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Business impact visualization for information security and compliance events

Mark Francis Tannian
Iowa State University

Business impact visualization for information security and compliance events

by

Mark Francis Tannian

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Major: Computer Engineering

Program of Study Committee:

Douglas W. Jacobson, Major Professor

Thomas E. Daniels

James A. Davis

Stephen Gilbert

Kevin P. Scheibe

Iowa State University

Ames, Iowa

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DEDICATION

I would like to dedicate this dissertation to my wife, Marcia, and my parents, Beatrix and Francis, who encouraged, supported and inspired my return to pursue this degree. I could not have achieved this lifelong aspiration without their love.

Although the thought is brief, my gratitude is deep for all the support and wisdom I have received from family, friends, colleagues and faculty.

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ABSTRACT

Business leaders face significant challenges from IT incidents that interfere with or pose imminent risk to more than one workgroup. Communication, coordination and monitoring are hindered by factors such as the IT incidents' technical complexity and unfamiliarity, distributed ad-hoc response teams, competing demands for their time, nuanced business dependencies, the lack of reliable IT incident measures and a piecemeal toolset to overcome these challenges. This research proposes a dynamic visual system as a solution to overcome many of these challenges.

Starting with a broad outline of improving the awareness and comprehension of security and compliance events for business leaders, this effort enlisted the assistance of seven experienced IT professionals in the Des Moines metropolitan area. A user-centered design methodology was developed that enabled these individuals to influence the selection of a problem space, explore related challenges, contribute to requirements definition and prioritization, review designs and, finally, test a prototype. The group consisted of leaders and senior technical staff working in various industries. At the end of the methodology, a group of unrelated IT professionals, with no prior knowledge, of the research was asked to perform an objective evaluation of the prototype. That evaluation is reported in this document and forms the basis of conclusions regarding the research hypothesis.

CHAPTER 1. PROLOGUE

1.1 Introduction

This chapter provides an overview of the research presented in this document. The next section of this chapter, "Problem Description," summarizes the problem being addressed in this research. The following section, "Investigated Solution," discusses the rationale for the approach taken to address the problem. The following section specifies the research hypothesis. A brief summary of how the research was conducted follows in the "Research Sketch" section. Contributions resulting from this research are presented in the "Contribution Summary" section. The chapter closes with a section titled "Document Overview," which describes the structure of this document.

1.2 Problem Description

This research identifies two problems: the first is a broad issue related to leadership's timely understanding of security and compliance issues; the second is essentially a sub-problem that is related to Information Technology (IT) incident management. IT incident management is a class of security and compliance decision-making that leaders must address in a timely and business-sensitive manner. This section describes the broader problem that motivated the general inquiry into business impact visualization. The description of the IT incident management sub-problem then follows.

1.2.1 Broader Problem

Today, managers depend upon subject matter experts to pre-process and pre-evaluate the significance of activity within the enterprise environment, and raise concerns if events surpass the analysts' perceived threshold of risk. In this operating environment, managers work at great conceptual and perceptual distance from significant events, putting them at a marked disadvantage, as their lack of understanding, awareness of simultaneous risk events, and limited dynamic access to event-context data increases response delay and uncertainty. Moreover, in less time-sensitive circumstances, business leaders are asked to evaluate risk remediation and attest compliance to standards and regulations without an intuitive understanding of the subject they are evaluating or to which they are attesting. Development of business impact visualization has the potential of enabling new and improving existing decision-making processes performed by business leaders.

1.2.2 Sub-problem

While there are a number of sub-problems associated with the broad problem described above, IT incident management is the focus of this research. Available literature and historical processes suggest that computer security incident management and IT operational incident management are, or should be, two distinct business management processes. Although there are significant differences between these two classes of computer-related incidents, broader management of these incident classes has become holistic, integrating both classes. As a result, this research draws upon literature and experience from both sub-disciplines within IT management.

IT incident management seeks either to prevent incidents or effectively respond to incidents that were not prevented[1]. An incident has a lifecycle that starts with symptoms. If the symptoms raise concerns, they are investigated to determine if a problem truly exists. If the problem exists, it is then escalated for potential classification as an

incident. If an incident is declared, the incident is responded to and then closed. As a means of process improvement, incidents are analyzed individually or in aggregate to determine what can be done to prevent similar incidents from recurring and improve response effectiveness. Authorized changes are implemented based on this analysis.

Although the root causes of non-malicious operational issues may not be readily apparent, ascertaining that the related symptoms are a problem worthy of escalation is relatively straightforward. By contrast, symptom analysis related to malicious activity is challenging in even moderately complex IT environments.

Certain incidents are sufficiently contained and promptly addressed by an authorized individual. Complex and wide-impact incidents, however, often involve multiple people and multiple teams. In these cases leaders are crucial, in that they must enable and authorize response in balance with ongoing business demands. Not all devised lines of inquiry or interim solutions are guaranteed to work, and often the impact of an incident increases as a result of the steps necessary to correct the problem.

Finding reliable numbers and statistics for IT incidents is a challenge. While there have been various attempts to collect statistics related to security incidents, a general IT incident census does not appear to have been taken. Although they have various weaknesses, the two most recognized reports are Verizon's annual "Data Breach Investigations Report" and Computer Security Institute's (CSI) "CSI Computer Crime and Security Survey." In order to identify the frequency and impact of the class of IT incidents being considered in this research, evaluators participating in this research were asked to provide approximate statistics relative to their environments.

Respondents to a pre-evaluation survey administered in this research reported that, on an annual basis, they had experienced a median of 62.5 IT incidents, with two respondents stating as many as 8,000 IT incidents. The size of a response team varied among respondents. The median maximum size of a response team was 25, with one reporting as high as 100 people. The median annual cost related to IT incidents reported

was $325,000, with one reported to be as high as over $1 million. There are data quality issues with these numbers, but they provide an interesting view. The survey is discussed in further detail later in this document.

The CSI report's scope in terms of IT incidents is restricted to security incidents, based on voluntary replies to a survey sent to members of the institute. The focus of the survey is on computer crime and security management. The "2010/11 CSI Computer Crime and Security Survey" reports that, in the twelve-month period from July 2009 through July 2010, 117 respondents experienced at least one security incident[2]. Not all attacks reported in this survey resulted in incidents. Based on 149 respondents, the Survey reports that over 10% experienced attacks that included malware, "insider abuse of Internet access or email," laptop or mobile device theft, denial of service, "bots on their networks," password sniffing, and "system penetration by an outsider" ([2],pg. 15 & 17). Among other types of attack, these may have resulted in the security incidents reported by the 117 respondents. The report was unable to provide information on the financial impact of these incidents, due to what Richardson describes as "[f]ewer respondents than ever are willing to share specific information about dollar losses they incurred" ([2],pg. 2).

The Verizon "2012 Data Breach Investigations Report" focuses only on security incidents that resulted in data breaches. The report is based on security incident data Verizon collected from their consulting efforts, as well as incident data provided by the Australian Federal Police, Dutch National High Tech Crime Unit, Irish Reporting and Information Security Service, Police Central e-Crime Unit of the London Metropolitan Police, and the United States Secret Service. The Verizon team consults on numerous security incidents, and they note that error and misuse, as well as availability losses, are likely more common than data breaches[3]. The report states that, within the reporting timeframe, 855 breach incidents occurred in IT environments hosted in 36 countries involving 174 million compromised records. Among their analyses, the report provides

a timing analysis across the phases of the breach-incident lifecycle. Table 1.1 contains the durations of lifecycle phases in orders of time magnitude as a percentage of breaches analyzed([3],pg. 49):

Table 1.1: Verizon 2012 DBIR Data Breach Incident Timing Analysis

Phase	**Seconds**	**Minutes**	**Hours**	**Days**	**Weeks**	**Months**	**Years**
Initial Attack to Initial Compromise	10%	75%	12%	2%	0%	1%	0%
Initial Compromise to Data Exfiltration	8%	38%	14%	25%	8%	8%	0%
Initial Compromise to Discovery	0%	0%	2%	13%	29%	54%	2%
Discovery to Containment/ Restoration	0%	1%	9%	32%	38%	17%	4%

In summary, this brief overview suggests that IT incidents occur in many environments, that there is a great variety of IT incidents, and that IT incident response is costly. The time duration from initial attack symptoms to initial compromise is a matter of seconds or minutes for many data breaches. Moreover, closure of complicated IT incident events can take days or weeks – possibly as long as years. IT incident prevention is the goal, but incidents will nonetheless continue to happen. The victim of an incident realizes no benefit from experiencing an IT incident. Response costs, productivity disruptions and possible revenue losses make incidents costly. Beyond these direct costs, there are potential losses related to reputation damage, penalties and opportunity costs. Therefore, improving efficiency in IT incident response is an important challenge that needs to be addressed. One means to improve efficiency is to aid business leaders in their

incident-related decision-making.

1.2.2.1 Clarification of Terms

Throughout the document the incidents of interest in this research are all IT-related. However, "incident management" in general is a problem space much broader than IT incident management (e.g. events related to fire, medical emergency, physical security, military activity, public health, etc.). This document uses the terms "IT incident" and "incident" interchangeably. Except on rare occasions, the term "incident" does not refer to non-IT incidents.

1.3 Potential Solution

Visualization geared toward IT incident management, particularly to the leaders' specific needs, was investigated. There is a significant body of research into the usefulness of visualization. In the introduction to a book of collected papers on information and knowledge visualization, Keller and Tergan review a body of literature to substantiate the value of visualization. They mention that investigations suggest that visualization can help users manage complicated and poorly structured topics[4]. Ware writes that the value of visualization lies in its ability to augment a person's limited visual and verbal memories by depicting intricate concept arrangements in an external visual presentation[5]. Moreover, Ware argues, the combination of a person's cognitive abilities with a computer-driven visualization is much more effective than a person left to their own innate mental abilities. Further, Novak and Wurst suggest that visualization can be used to bridge communities of practice that have distinct approaches to finding meaning and significance in information and information structures[6].

There are at least two communities in IT incident management, including technical responders and business-oriented responders. Visualization may be a means to provide

the necessary scaffolding with which leaders can engage in responses to IT incidents from zero awareness. Furthermore, visualization may be able to provide convenient, albeit possibly complex, visual structures to maintain the awareness and understanding necessary for IT incident management. Although this research is limited to investigating a means for improving leader awareness and comprehension of security and compliance decisions, the work done by researchers such as Novak and Wurst suggests that visualization may be a means for achieving a common understanding of IT incident management challenges across professional disciplines.

1.4 Research Hypothesis

This research was initiated with the following broad hypothesis: "It is possible to improve business leaders' awareness and comprehension of information security and compliance decisions through a dynamic visual system." This broad scope facilitated the investigation into a range of possible sub-problems.

With IT incident management selected to be the focus of this research, a refined hypothesis evolved and better aligned with the selected sub-problem. The refined hypothesis: "Business leaders face significant challenges from IT incidents that interfere with or pose imminent risk to more than one workgroup. Communications, coordination and monitoring of IT incident handling can be greatly enhanced by use of a dynamic visual system. Further, leader effectiveness can be improved by enabling more timely awareness and comprehension of the organization-performance implications of incident related decisions. By designing, prototyping and evaluating an IT Incident Visualization System this initial research probes whether improved awareness and comprehension claims are justified."

The business leader is defined as a person who has responsibility and authority to make decisions or exercise judgment on behalf of an organization regarding IT incident

management matters that affect business impact or risk. Organizations that may benefit from this research are not limited to profit-oriented firms. Any organization, including non-profits and government, using IT to enable their objectives should find benefit in this research. In this context, the term "business" refers to the function or purpose of an organization or its organizational units.

1.5 Research Sketch

In an effort to explore the potential value of business impact visualization in improving decision awareness and comprehension, a prototype was developed informed by a user-centered design approach. IT professionals needed a prototype for these concepts to be sufficiently tangible in order to facilitate evaluation through interaction and application. These professionals were asked to evaluate the prototype's potential for improving their decision-making, and to determine the broad potential benefit of visualization to the selected problem space overall.

Starting with a broad outline of improving the awareness and comprehension of security and compliance events for business leaders, this effort enlisted the assistance of seven experienced IT professionals in the Des Moines metropolitan area. These individuals influenced the selection of a problem space, explored related challenges, contributed to requirements definition and prioritization, reviewed designs and, finally, tested a prototype. The group consisted of leaders and senior technical staff working in various industries. At the end of the methodology, a group of unrelated IT professionals with no prior knowledge of the research was asked to perform an objective evaluation of the project. That evaluation is reported in this document and forms the basis of conclusions regarding the research hypothesis.

1.6 Contributions Summary

This research makes three significant contributions to the security visualization field. The contributions are Iterative Field Study Methodology, IT Incident Visualization System, and Practitioner-Oriented Evaluation Framework. The contributions are interdependent, but could be decoupled and used in other security visualization contexts. This section briefly introduces these contributions, more extensive descriptions of which will be found in later chapters of this document.

1.6.1 Iterative Field Study Methodology

Although the adoption of user-centered design within the security visualization community is fairly common, this methodology embraced the commitment to user-centered design by allowing the input of collective voices from a stable set of area IT professionals to be incorporated pervasively throughout the design process. This methodology introduced an objective assessment of the end result by relying on a separate set of IT professionals.

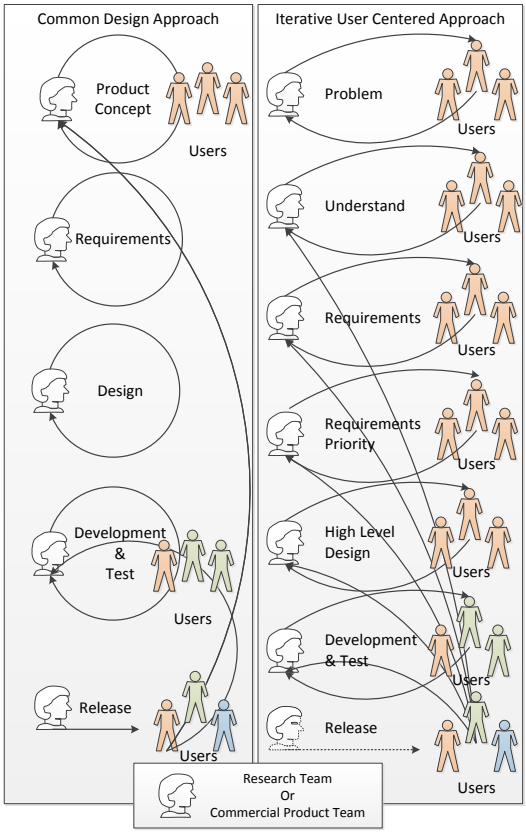


Figure 1.1: Design Approach Comparison

Figure 1.1 compares a fairly common approach to product design to the approach taken in this research. As a point of clarification, a product release was not intended from this research.

As shown in Figure 1.1, in a more traditional design approach product development teams tend initially to target a market or challenge area for their product. They will consult with customers, eliciting customer needs regarding the solution the product team is interested in creating. The team may return to the same customers, as well as possibly recruiting others to test preliminary versions prior to release. Customer feedback on this preliminary testing has the potential to greatly influence the feature set early on; but as customer testing proceeds, stability and performance become the primary objective. After determining that it has been sufficiently tested, the product is then released to

all those willing to buy it or those who may have sponsored the product's development (e.g. in-house development projects). Further feedback on this release will influence needs analysis for a future version of the product or initiate product corrections by the development team.

The iterative field methodology used in this research explored the problems being faced by users before selecting a problem on which to assist. These same users strongly influenced the choice of a problem space. Efforts were made to explore the nature of the chosen problem space and the challenges within it. With this understanding, requirements were developed and reviewed with these users. In turn, these users shared their preferences regarding these requirements, which led to requirements prioritization. From these requirements, high-level designs were constructed and then reviewed by the same group of users. Armed with these design insights, a prototype was developed. These users tested the prototype and provided additional input that further motivated prototype changes. A separate set of users tested the prototype as well. The cycle between development and user evaluation could have multiple iterations prior to any release to a broader audience.

This approach relies heavily on a set of users for guidance. Their guidance was complemented by supplementary knowledge sources that included related literature and researcher background. The objective of this approach was to reduce the likelihood that the research hypothesis would fail to be validated due to a gross mismatch between a design based on a researcher's limited worldview and the intended user community.

1.6.2 IT Incident Visualization System

Business impact visualization started out as a broadly scoped research topic. The field study directed the focus of this research toward IT incident management. The focus was specifically on IT incident response and followup to IT incident closure. The security visualization community has done impressive work in incident identification, but has for

the most part left incident response for others to address.

IT incident response is a team effort consisting of technical responders as well as leaders who serve in various capacities. Several of the leader roles were the focus of this IT Incident Visualization System design effort. Design efforts were devoted to the "Incident Coordinator," "IT Leader" and "Business Leader" roles. The implemented functionality in a medium-fidelity prototype was directed to the IT Leader. A medium-fidelity prototype is a software implementation of design concepts sufficiently complete for someone to perform limited autonomous interaction with, but without the algorithms, libraries and other functionality that would allow it to operate in a real-world setting. Data provided was manually constructed, due in part to the absence of needed sources. The software development necessary to integrate with real data sources was beyond the scope of this effort.

The IT Incident Visualization System was intended to provide interfaces based on the role assigned to a particular user. A user may be assigned to multiple incidents for which he or she is assigned a different role. The visualization provided access to information in the areas of incident awareness, response awareness and coordination, and information support. Field study input directed this effort to go beyond awareness and clarification by allowing an authorized leader to influence the response from within the visualization.

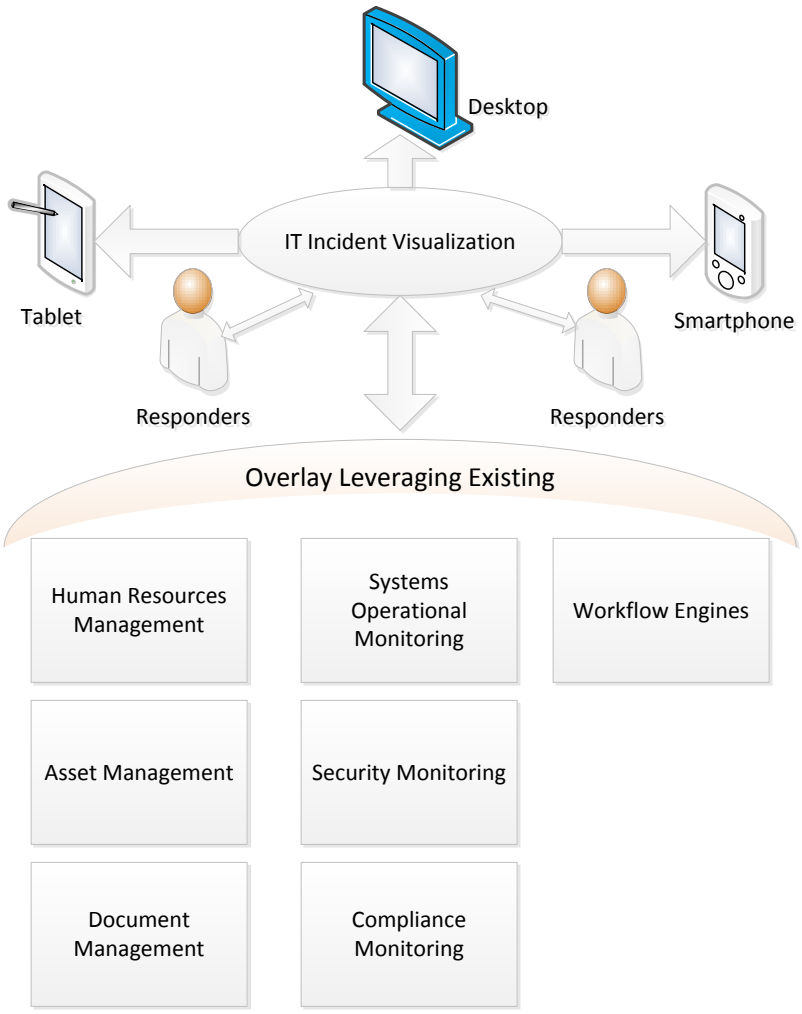


Figure 1.2: Visualization's Environmental Fit

Conceptually, the visualization was not intended to be a replacement for existing systems that provide authoritative information needed for response. Rather, the visualization was meant to provide a view into existing data repositories and interfaces with existing systems, such as workflow systems that facilitate work assignments within an organization. In a sense, the visualization is a composite service that provides the supplementary content needed for effective IT incident handling. Figure 1.2 presents a broad sense of how the visualization fits into an IT environment.

1.6.3 Practitioner-Oriented Evaluation Framework

In order to proceed with an objective, independent validation of the research hypothesis, it was necessary to build a framework to make that possible. Ideally, a sufficient number of randomly self-chosen IT professionals, volunteer IT professionals who respond to a general call for participation, participate in order for credible inferential statistical analysis to be performed. This objective required evaluations to be conducted in a repeatable fashion in order to minimize researcher influence on the data being collected. Time restrictions and logistical considerations required that multiple evaluators needed to be accommodated in order to collect a large enough sample. The framework is a composite of procedures, software, data-collection instruments, structured activity design and data.

A crucial dimension to the framework is the context necessary for participants' consideration while performing their evaluations. The decision-making associated with IT incident handling is context-sensitive. If there was one common decision to be made during two IT incidents at the same point in the response, it would be very likely that the differences between the incidents would prompt two different decision outcomes. The environment in which an IT incident occurs has significant bearing on decision-making as well. These contextual factors make up a large portion of the comprehension aspect of decision-making. It is these contextual factors that the IT Incident Visualization System strived to make accessible and understandable.

Although this framework was developed to facilitate the final stage of a specified methodology for a medium-fidelity IT Incident Visualization System prototype, there is much that can be repurposed to facilitate evaluation of other medium-fidelity prototypes as well as high-fidelity prototypes within the security visualization field.

1.7 Document Organization

This document has seven chapters beyond this one. The second chapter explores the relationship of this research to the current literature. The third chapter discusses the "Iterative Field Study Methodology" used to develop a possible visualization approach for assisting business leaders. The fourth chapter discusses the design of the developed "IT Incident Visualization System." The fifth chapter explores the "Practitioner-Oriented Evaluation Framework" that was developed to validate the IT Incident Visualization System. The sixth chapter analyzes the results from the evaluations that were performed. Chapter seven closes the discussion of the work to date with "Observations and Discussion," and the last chapter discusses areas of future exploration. Finally, a number of appendices containing supplementary information are provided.

CHAPTER 2. REVIEW OF LITERATURE

This research into business impact visualization has been multidisciplinary, drawing from various fields to design and implement the IT Incident Visualization System in order to test a research hypothesis. The focus of this research has been to provide substantive contributions to the field of security visualization. As such, the literature review is focused within the body of work produced by other researchers in the security visualization community (often referred to as "VizSec").

The literature review is organized to align with this research's three contributions of IT Incident Visualization System, Iterative Field Study Methodology and Practitioner-Oriented Evaluation Framework. The first portion of the review relates the literature to the IT Incident Visualization System. The second subset emphasizes design methodologies used in security visualization research. The third area focuses on evaluation and the structures promoting reliable assessment. The last section of this chapter provides a synthesis and summary of how the work of others relates to this research.

Some of the work was chosen for an extended treatment based on the number of aspects in common with the three research contributions. The discussion of these works extends beyond the scope of the section containing them in order to avoid repetition.

2.1 IT Incident Visualization System

There are numerous papers that reference the term "incident" in many contexts. One common use of the term connotes the meaning of an IT activity or event that is anomalous

and possibly malicious, and that needs further investigation in order to ascertain possible motivations and consequences resulting from the incident to date (e.g.[7][8]). There is a reasonable likelihood that the identified activity is non-malicious and/or of little to no consequence. The term "incident" in this research is associated with activities or conditions that have been confirmed as being an IT problem and that warrant a directed response.

Many of the visualization efforts to date have been related to supporting IT personnel in pre-incident or forensic analysis (e.g.[9][10]); support for less tactical decision-making has come about only more recently. Up until recently, the security visualization community largely has not investigated solutions in support of leaders. An explicit attempt to support the leader was reported by Erbacher[11], who describes a user-centered approach to improve high-level situational awareness for both network analysts and first-line network managers. Erbacher's design focuses on providing situational awareness by presenting impact and vulnerability assessment. The usefulness of this solution appears primarily related to pre-incident analysis and supporting decision-makers' understanding of environmental conditions that may influence incident declaration and response actions. The objective of the IT Incident Visualization System was to support leaders as well, but only after an incident is declared. Situational awareness was constructed by providing financial, operational, compliance and security impact status of the incident, as well as technical (e.g. systems) status.

Another recent paper sketches out an initial effort to support decision-making processes related to computer network defense[12]. Horn and D'Amico appear to imply that their efforts were for internal use only; however, given the strategic nature of the decisions they attempted to address, their visualization certainly has the potential to support leaders in their decision-making. They designed their tool to organize data classification and data collection consistent with Endsley's "Goal-Directed Task Analysis" framework. This consulting tool initially appears intended as a process-improvement tool that allows

for analysis across multiple incidents, and that can inform decisions related to making changes in future defense processes in addition to data collection and analysis. The intention of process improvement is consistent with a requirement identified for the IT Incident Visualization System, but the requirement was not addressed in this round of research. Up to this point, the IT Incident Visualization System has been focused on facilitating leaders' response decisions related to active incidents on a per incident basis.

Rasmussen et al. presented NIMBLE (Network Intrusion Management Benefiting from Learned Expertise), a tool designed for use in a Security Operations Center (SOC)[13]. Their visualization is an analyst's tool intended to improve the performance of those who keep watch on security monitors and analyze security event anomalies. The tool provides an interactive, graph-based presentation of Intrusion Detection System (IDS) alert data, as well as presenting recommendations based on automatic matching to potentially relevant historical analysis in order to assist with the classification of reported activity. Like many other visualization efforts, this analyst's tool is meant to assist in performing triage on activities that could potentially result in reporting credible alarms of malicious activity.

What distinguishes Rasmussen's effort relative to others is the user-centered approach to determine requirements by eliciting analyst feedback on low-fidelity prototypes. Moreover, the evaluation framework employed is documented. Rasmussen et al. designed their evaluation to be a fully balanced parametric experiment, performing a comparison between their graph-based display and a tabular view. Additionally, they tested the effectiveness of the recommendations by varying their presence and the qualities of the recommendations on a per-evaluation task basis. They report evaluating in structured activities with 18 professionals, each with at least three years of experience. Evaluator judgments made in each evaluation scenario are compared to prior established judgments for those decisions.

There are a number of similarities between Rasmussen and the Practitioner-Oriented

Evaluation Framework, namely having professionals evaluate the proposed solution, repeatable evaluation structure, and assessing decision quality against predetermined correctness. One significant difference is in evaluation objectives. The hypothesis tested in the IT Incident Visualization System research is a broader question than whether a substitute design is better than an existing tool. Among other data, Rasmussen collected qualitative data through informal verbalized feedback from those with time remaining, as opposed to using a structured approach to collect feedback from everyone who participated.

2.2 Iterative Field Study Methodology

When reviewing the security visualization literature, one can see that many security visualization design teams do not utilize a user-centered methodology. There are, however, researchers who have embraced the notion that viable solutions require input from the user at various points in the development process.

Conti's visualization security dissertation was influential in the structure of this project's Iterative Field Study Methodology[14]. His user-centered approach involved two separate populations over the course of his research. First, Conti collected user needs through a survey completed by professionals at security trade conferences. From this input, he generated requirements and designed a prototype. To test his prototype, Conti used a set of master's-level students and a set of senior undergraduates, all with sufficient background to perform quantitative tests. The entire cycle of research was motivated by a fairly abstract research hypothesis. The use of students for evaluation may have been expedient, but is not representative of the audience that appears to have been the intended users of the tool. This may not have been a concern for Conti; however, for the research being presented here, the hypothesis specifies the type of user for which the visualization was developed. Conti did not return with intermediate results for further

user input beyond the initial needs collection and final evaluation. The methodology for the present research, discussed in detail in a later chapter, avoids this shortcoming.

Although the paper written by D'Amico and Whitley does not introduce a visualization concept for security visualization, they do provide a compelling report on the results of a cognitive task analysis of the work performed by computer network defense analysts[15]. This offers insight into the various roles and tasks these analysts performed. Though D'Amico and Whitley's targeted subjects were not leaders, these reported insights inform the present research, filling a few gaps in the field study results. Although the tasks of leaders are different, they have cognitive support needs in common.

In the context of the history of the Workshop on Visualization for Computer Security, Komlodi et al. was one of the first teams to publish on attack-identification visualization research efforts based in user-centered design. Komlodi used knowledge-elicitation techniques, including *in situ* contextual interviews with practitioners[16], early prototype demonstration to a focus group, and end-user usability evaluation of a later functional system[17][18].

Komlodi's research involved 16 professionals across the three user-centered activities. Contextual interviews were done with nine practitioners having a variety of responsibilities and backgrounds. They performed their demonstration for a focus group that consisted of seven members of an IDS user group. The pool of four end-user usability evaluators was made up of volunteers from among the initial nine contextual interviewees. In essence, the group had 12 unique professional viewpoints in its study. A strict accounting comparison shows that, for the execution of the Iterative Field Study Methodology, a group of seven professionals was consulted repeatedly during design efforts. After completing the development phase, a verification phase was performed with an evaluation that elicited feedback from 17 unrelated professionals for a total of 24 unique professional perspectives.

Although requirements were developed iteratively as a result of the initial contex-

tual interviews and the subsequent focus group's response to a low-fidelity prototype, Komlodi's participants were not consulted either to comment directly or to prioritize the collected requirements. Their usability study provides further insights for additional iterations, but the participants were commenting only on manifestations of requirements and not the requirements themselves. The Iterative Field Methodology effort followed a similar approach to requirements collection, but the fundamental requirements that led to the high-level design and subsequent medium-fidelity prototype were reviewed and prioritized by members of the initial group of seven.

Fink et al. performed a multi-step, user-centered effort to develop a meta-visualization that incorporated collections of visualization tools for presentation on numerous large high-resolution displays in a massive interactive workspace[19]. They first interviewed eight experienced analysts and viewed four others using the large displays within the context of a sample problem. They followed this effort by designing mockups that suggested effective uses for these large display environments, and then returned to the analysts for feedback on the mockups. The sample data used to provide context for the interviews and observations was fabricated by another source in preparation for the Visual Analytics Science and Technology (VAST) 2009 challenge. The researchers used a subset of VAST data that presented the challenge of a scenario requiring analysis of multiple data sources in order to determine whether an insider was inappropriately sending sensitive information beyond the security perimeter of a mock embassy.

Unlike the effort by Fink et al., which assumes an initial solution, the Iterative Field Study Methodology started with a broad inquiry and focused on a problem and subsequent design approach based on participant input. Fink et al. report a number of ergonomic challenges (e.g. snow blindness) and practical challenges (e.g. heat) associated with having eight thirty-inch panels arrayed over a desk. Their paper appears to imply that they started with the assumption that an eight-panel array would be a viable solution. Given the chance to influence the panel quantity and configuration, would the

analysts have provided input that might have suggested a different approach?

The VAST 2009 challenge data set provided mock log data that followed challenge-specific conventions with respect to content structure and semantic significance. Although the source types were fictional, the building access control and network traffic sources that were conceptualized are reasonably common. By contrast, the Practitioner-Oriented Evaluation Framework addressed a problem with no established conventions beyond the isolated tools currently utilized. An implementation analysis of an IT Incident Visualization System leveraging the concepts presented in this research would probably determine either that some source types do not currently exist, or that the sources are not typically accessed or leveraged in the manner necessary for the proposed concepts to be functional. Accordingly, this would require an uncommon assembly of data sources and data with interrelationships not previously considered.

The research of Foresti et al. in situational visualization resulted in a project called "VisAlert"[20][21][22]. This visualization effort is one of the most referenced works within the security visualization community. The visualization is a network security analyst's tool that is able to incorporate network and host intrusion-detection sensor data. The researchers document how they went from sketches to a field-test-grade prototype[20]. Documenting a number of aspects of their user-centered design approaches[21], Foresti et al. utilized an interdisciplinary approach that leveraged their team members' backgrounds. Their methodology was recursive, allowing for internal and user evaluation to trigger returns to previously performed stages informed with new information. Although the details are not available, they performed cognitive analysis studies in order to analyze aspects such as network security analysts' problem space, mental models and tasks.

Foresti et al. recruited a security assessment expert to construct a data set that would allow them do what appeared to be internal walkthrough tests in order to validate their design prior to field testing. For the apparent purposes of performance and integration testing, they drew upon a large, restricted-availability test-data set developed for the

intelligence community by Defense Advanced Research Projects Agency (DARPA). This data set contained raw logs from network services applications, operating systems, and network packet data, in addition to supporting context such as network topology and scenario descriptions. Eventually, the researchers deployed a test implementation at a military research lab, where experienced analysts used the tool and provided feedback. The team once again returned to design and development and refined the tool based on the analysts' input. Formal evaluation testing was being planned, but a related publication was not found.

As a point of comparison, the Iterative Field Study Methodology started with a user-centered challenge analysis and ended with user input useful for further work. Foresti's resources and implied mandate must have been significantly larger. Starting with concept and achieving deployment-grade software must have been a significant effort. When putting development progress on an equal footing by comparing some initial design implementation of VisAlert and the medium-fidelity IT Incident Visualization System concept prototype, there are considerably more user-centered touch points in the Iterative Field Study Methodology. These points of user-centered influence occurred during requirements review, requirements prioritization, high-level design review, prototype review and independent prototype evaluation. Foresti et al. performed a significant amount of interpretation and design to reach their first usability test without further interaction with the user. Reconciling their papers was somewhat challenging, but it would appear that their first usability test took place when they implemented an "alpha test" at the research lab[22]. Assuming conventional use of the term "alpha software," the chosen set of major functionality was nearly complete, although operationally unstable.

Erbacher et al. published a paper titled "A multi-phase network situational awareness cognitive task analysis"[23]. The results of this task analysis informed the design of the visualization reported by Erbacher in the previously mentioned paper[11]. Their Cognitive Task Analysis process has nine steps, starting with an initial brainstorming

session and ending with a program manager review. This is the first task-analysis process encountered that involved managers in addition to analysts, with both groups designated as targeted users who were involved in five of the nine steps. The manager viewpoint was incorporated in the first two steps, brainstorming and individual interviews, but does not appear to be involved again until possibly the program manager review. Step 5 involves analysts brainstorming and discussing task execution in the context of multiple prepared scenarios. The last-mentioned user-oriented step is step 7. In this step, six low-fidelity design alternatives developed in step 6 were presented to analysts for comment. This led to the selection of two designs for implementation in step 8. They go so far as to support the DARPA-sponsored restricted-use data set that Foresti et al. use. At step 9, the program manager reviewed the outcome of step 8. It is unclear whether the assigned federal program manager had experience as a first-line network manager. Hence, it is not clear from the authors' description that the targeted manager role was represented at the review in order to contribute to the assessment of the final development outcome.

Erbacher's research started with the much more concrete objective of improving pre-incident situational awareness for both analysts and managers. In comparison to the Iterative Field Study Methodology, they were able to focus their inquiry earlier and reduce the number of steps needed to reach an equivalent independent evaluation. Although their paper documents visualization requirements in combination with the scenarios developed in step 4, it is not clear that the user had an opportunity to directly influence the requirements or their prioritization. The absence or lack of documented accounting for manager participation past the initial interviews is an implied contradiction of their objective of repeatedly returning to the user in order to seek guidance as the design progressed. By contrast, the leader role was the sole focus of the IT Incident Visualization System, and leader roles were represented in each user-centered phase of the Iterative Field Study Methodology. It is unclear whether those taking part in Erbacher's program review had the opportunity for an individualized, interactive hands-on-situated experi-

ence. Those independent professionals who took part in the IT Incident Visualization System evaluation most certainly did.

Guenther et al. introduced two new ideas to the community[24]. They suggest that multi-touch interactivity (e.g. Apple iPad interactivity) will improve network security analysts' ability to perform their analytical duties. They also suggest an alternative approach to user-centered design. Instead of relying on Cognitive Task Analysis to elicit design requirements, they suggest methods based on Activity Theory. Beyond introducing concepts related to Activity Theory, they do not document the Activity Theory-based method that led to their multi-touch design, nor do they report any user testing of their solution. Discussion of the Guenther paper could have been postponed until the later discussion of future work, as the further investigation of Activity Theory might merit future incorporation. The purpose of having the discussion in this section is to illustrate that design methods are an active discussion within the community.

2.3 Practitioner-Oriented Evaluation Framework

The nature of user evaluation of visualization solutions within the security visualization community is a mixed bag. These range from informal feedback collection based on walkthroughs to carefully designed and executed hands-on user assessments. Evaluation goals are commonly related to collecting detailed usability feedback. There have been evaluations that compare user performance when using a new approach against established alternatives such as tabular views or popular network analyzers (e.g. Wireshark). Those who attempted to obtain reliable results would formulate the evaluation tasks to be performed and carefully managed their order of execution.

A fairly common managed-evaluation event format appears to be one in which the participants are briefed on the research, provided training on the tool(s) to be used, and then perform tasks using the new solution and, possibly, an established tool as well;

the event then ends with participants providing feedback either informally or through a survey. Task completion time is monitored in the comparison tests, and in some cases the expiration of allotted time results in warnings. The limited review of structured evaluations does not make clear how participants are made aware of their tasks or how they communicate the outcomes of their task-related efforts. Rasmussen ([13]) dedicated a small portion of the interface to the capture of the task outcome and provided a time-remaining indicator for the task at hand.

Beyond the previous references, there is one paper worth noting related to evaluation. Goodall reports on a comparative evaluation designed to be of a repeated measure within subject design[25]. At the time of writing, Goodall commented that user testing was still unusual within the security visualization community. In context, the term "user testing" appears to be related to the empirical testing of a visualization solution's efficacy with respect to improving user performance. Goodall recruited eight students for the test. The students' participation consisted of being briefed on the research and the two tools to be evaluated, getting training on one of the two tools, completing a set of timed tasks using one tool, getting training on the second tool, completing another set of timed tasks with that alternative tool, and, finally, providing satisfaction feedback via a survey. It is unclear how long this procedure took.

Goodall mentions that the evaluation tasks were either "well-defined" or "exploratory." Well-defined tasks had one possible correct answer, while exploratory tasks required participants to draw one of many possible conclusions. Well-defined tasks consisted of multiple questions. The mechanism used to provide the task details to the participant is not documented, and it is unclear how the participants' conclusions were captured. However, Goodall mentions that a student and a researcher walked through a series of tasks together during the training. It is likely the researcher remained to observe and manage the task-delivery process and task-outcome collection.

The data set for the evaluation appears to have been arbitrary subsets of data origi-

nating from the HoneyNet Project. This approach to assembling the evaluation data set is likely a symptom of the functional value that traffic analysis tools provide in terms of offering environmental information in the context of what is being analyzed.

The time committed by each participant was not documented, and the training segments had no time limits, thus allowing participants to become familiar with each tool at their own pace prior to using it. It is reasonable to think that each participant committed at least two hours to complete the entire sequence of activities. Goodall notes that each student had taken at least one course in computer networking, but it is not clear if the students had any background in relevant analysis strategies to complement the functional training on each tool. Goodall explains that experts were not chosen because they would likely have distorted the results, i.e. experts would have been exceptionally proficient using the mainstay tool for comparison with the visualization, thus resulting in the mainstay outperforming the visualization solution for which the experts would have had relatively little training.

In the context of the Practitioner-Oriented Evaluation Framework, it was unreasonable to expect independent professionals with no stake in the research to devote more than 90 minutes. Any comparison between Goodall's evaluation and the IT Incident Visualization System concept evaluation is therefore inappropriate, as user performance and concept validation are very different test objectives. Yet, some of the evaluation tasks developed within the Practitioner-Oriented Evaluation Framework align fairly well with Goodall's idea of well-defined and exploratory tasks. Still, in all cases the range of outcomes was constrained by a fixed list of options, as opposed to Goodall's support for a broad range of outcomes.

2.4 Summation

Visualization support for handling an IT incident after the incident has been declared has not been investigated up to this point. Furthermore, business leaders have been underserved in the security visualization research community. Of the research potentially oriented toward business leaders, it is uncertain how involved these leaders were in design review and evaluation processes.

The employment of user-centered design methodologies is not uncommon, but has not been universally adopted. Among user-centered approaches, most researchers made significant assumptions regarding viable solutions prior to their first user-centered session. Beyond collecting sufficient user input in order to develop requirements, the requirements were not user-evaluated until well after being implemented in mockups or prototypes. By contrast, the methodology used in this research sought out user needs prior to making design assumptions. Moreover, the requirements were directly influenced and prioritized by the user community.

Many researchers did attempt to elicit user comment on their efforts prior to publication. In many cases informal feedback was sufficient for the researcher. The independence of the users consulted is not discussed in any of the work reviewed. Some researchers do note when they returned to people they had consulted previously, and in certain cases it is clear that those who participated in the evaluation were different. But the lack of transparency regarding organizational affiliations and contract relationships of the users makes social independence a challenge to determine in many cases. Significant efforts were made during the execution of the Iterative Field Study Methodology to ensure that final evaluation feedback was collected from professionals with no prior connection with the research, as well as limited ties to the Information Assurance Center.

The Practitioner-Oriented Evaluation Framework designed for this research was the result of a combination of research objectives, including concept-oriented prototyping,

concept-validation evaluation objective, convenient independent professional participation in evaluation, the business leader as targeted user, the information requirements of aiding IT incident handling, and progressive situation assessment and related task execution. This combination of objectives had not been addressed before, thus making a custom evaluation framework necessary.

Although each of the three main contributions are original with respect to the security visualization community, the literature review shows that these contributions have commonalities with other efforts to suggest that they could be of interest to the community and have been developed into a reasonable form.

CHAPTER 3. ITERATIVE FIELD STUDY METHODOLOGY

The methodology presented in this chapter centers upon the intended user. This chapter will delve into the details of this methodology, including some intermediate results.

3.1 Introduction

The Iterative Field Study Methodology was designed to leverage the notion that user-centered design results in designs that are more consistent with user expectations and improves the likelihood of a usable human-computer interface by the intended user group [26],[21],[27]. This methodology was iterative in that, as the research progressed from problem definition to a resulting tangible visualization, a stable collection of user-community representatives was repeatedly consulted. While a single researcher executed this methodology, a team of researchers could also adopt the procedure.

This methodology hinged on the cooperation of two distinct and independent representatives of the user community. The first group of community representatives was called the "Study Group"; the second was called "Independent Professionals."

The two groups had complementary purposes. The Study Group provided input that shaped both the scope and nature of intermediate research outcomes, while the Independent Professionals group performed the final validation role. Beyond the primary validation of whether a resulting visualization system achieved an overall research hy-

pothesis, the Independent Professionals provided an indirect check on whether the Study Group's input was reasonable, and whether its insights were properly captured, analyzed and integrated. By continuing beyond the validation performed by the Study Group, this method attempted to determine the general application of the insights gleaned as well as the resulting visualization. It also avoided the influence of any emotional investment in the final results that may have developed between Study Group members and the project, as well as between members and the researcher. The Study Group knew that their ultimate objective was to assist in developing a visualization that would, in fact, be evaluated by other professionals, thus giving them context from which to draw their insights and feedback.

Although members from both groups broadly represented the same user community, there were nonetheless significant differences among them. Each member of a group met designated qualifications. With only the broad goal of improving security visualization for business leaders initially, the backgrounds or professional roles of Study Group members were not precisely consistent with those of the Independent Professionals. The reductive, focusing nature of the methodology led to isolating a particular leadership role, which meant certain members of the group spoke less authoritatively when role-sensitive inquiries were made. Although this lack of authority did not exclude their involvement and contribution of useful insights, it further reinforced the need for the Independent Professionals group.

The Study Group as a population was stable at a size of seven, with the seventh joining after the initial field stage was conducted. Their ongoing involvement was in large part determined by the alignment between their availability and the research schedule.

The Institutional Review Board (IRB) reviewed and approved the execution plan for this methodology.

3.2 Methodology

The methodology developed for this research expands upon a fairly common product development practice described by Ulrich and Eppinger[28]. The methodology was comprised of a number of stages, as depicted in Figure 3.1. The stages have been placed in two columns. The left column is titled "Researcher Activity," indicating that these stages were performed without involving user-community representatives. There are two stacked columns on the right side of the figure. The top right column is the set of activities involving the Study Group, while the bottom right represents those performed by the Independent Professionals. The need to progressively reduce and narrow the scope of research prior to investigating the next level of detail is represented by an inverted triangle in the background of the figure, with key scope-of-research milestones indicated on the left of the graphic.

There were additional dimensions associated with the stages involving the Study Group and Independent Professionals. The rims of the stage objects are either solid or dashed, indicating whether a given stage's purpose was, respectively, either a continuation of the forward progression in reaching the stage of prototype evaluation (solid) or a touch point seeking confirmation of understanding as well as prioritization (dashed). Most interactions with the Study Group were done in a one-on-one setting, with each participant speaking from his or her own perspective and understanding. These isolated meetings elicited ideas that needed to be identified, interpreted and consolidated prior to incorporating them into the larger body of knowledge. As indicated by the stages with dashed borders, it was necessary to return to the Study Group to ensure that the researcher understood the member(s) correctly, and that there was general agreement as to what was learned. Beyond this confirmation, it was also necessary to make choices before moving forward. In this user-centered approach, these choices were heavily influenced by the priorities the study participants shared with the researcher.

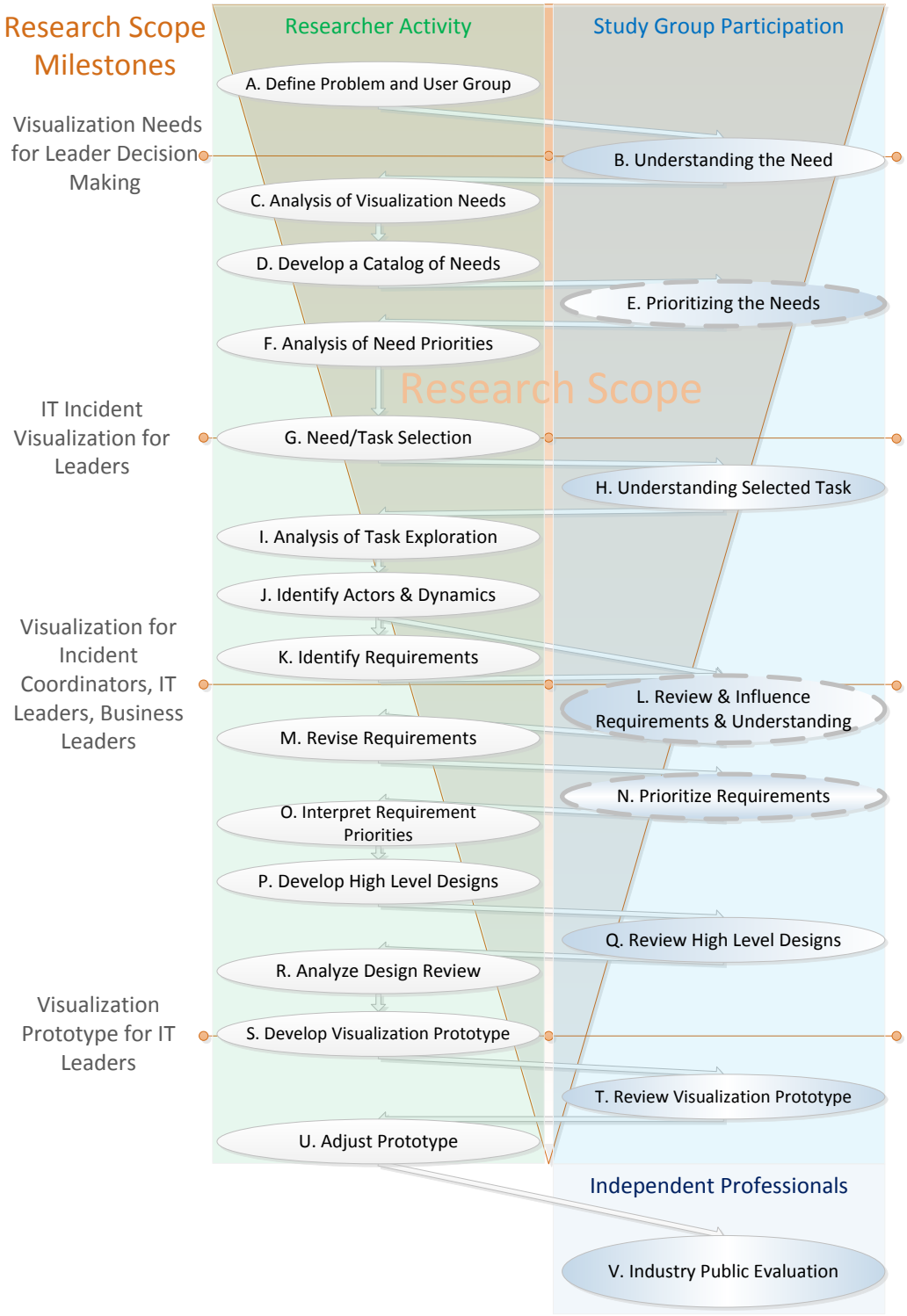


Figure 3.1: Iterative Field Study Methodology

The second and somewhat subtler dimension illustrated in Figure 3.1 is the shading gradient in user-community stages. The shading gradient provides an indication of the common tools used to elicit responses across the stages. Table 3.1, below, describes the relationship of these elicitation tools to the particular stages. For the sake of brevity, a detailed description of the tools will not be provided; further description of how the tools were used can be found in the stage descriptions that follow. Any literature used as guidance to develop the actual tools is listed in Table 3.1.

Table 3.1: Methodology Stages: Tools and Related Literature

Stages	**Tools**	**References**
B, L, Q	Semi-structured interview	[27], [29], [30], [31]
E	Informal Voting	-
H, T, V	Blend of Tools - H: Semi-structured interviews, concept maps T: Pre- and Post-surveys, cognitive probe survey testing, semi-structured interview, prepared hands-on experience V: Pre- and Post-surveys, prepared hands-on experience	H: [27], [29], [30], [31], [32] T: [33], [34], [35], [36], [37], [38],[39] V: [38]
N	Analytical Hierarchical Process	[40], [41], [42]

3.2.1 Recruitment

Although not included in Figure 3.1, recruitment was an important stage encompassing two phases. The first phase was to assemble the Study Group. The second, was to invite another set of professionals to participate in the Industrial Public Evaluation.

3.2.1.1 Study Group

Recruitment was conducted by emails sent to IT professional mailing lists, such as InfraGuard and Information Systems Security Association (ISSA), as well as by direct

outreach to professionals. Criteria for participation in the Study Group required prospective participants to be technology professionals responsible for considering the effects of information security and compliance events on their organizations. The initial commitments participants were asked to take part in three to fifteen sessions over a period of 12 – 18 months, with a total time commitment of up to approximately 15 hours.

Table 3.2 shows the high-level professional characteristics of those who joined the Study Group, as well as their levels of participation. The median number of sessions was 15, with the median time spent by Study Group participants at nearly 19.5 hours. There were, in total, 80 distinct knowledge-gathering sessions, representing roughly 115 total recorded hours of professional participation. The time reported in Table 3.2 was based on interview recording lengths. Social and administrative activities such as scheduling, greeting and miscellaneous conversations, as well as the requirements prioritization effort, were not included. The reported professional biographical information was collected at the first session.

Participant ID 499, who joined the study after the IT incident management topic area was selected, was an outlier in terms of IT experience and professional role. This participant provided broader incident management context to the study, given the participant's firefighting, Emergency Medical Technician (EMT) and natural disaster training and response experience. Participant 499's contribution to the study was limited to Stages H and Q, as indicated in Figure 3.1.

3.2.1.2 Independent Professionals

Given the research objective of independence for the final evaluation, and limiting bias due to familiarity with the researchers and topic, members of the Independent Professionals group were recruited indirectly using the following mechanisms:

- General calls for participation through professional mailing lists and forums, including InfraGuard, ISSA, ISACA, and the Iowa Technology Association;

Table 3.2: Study Group Members - Backgrounds & Participation Summary

ID	Business Sector	Role	Years IT Experience	Years with Employer	Session Count	Total Time	First Session Date	Last Session Date
166	State Government	Network Security Administrator	26	27.0	15	20:01:11	3/4/10	9/24/12
191	Financial Services	Director of Risk Management	18	4.0	15	23:27:05	2/3/10	9/28/12
270	State Government	Senior Network Administrator	35	34.0	7	9:32:38	3/8/10	4/19/11
400	Insurance	Vice President, Enterprise Information Protection	19	7.0	18	19:22:45	2/2/10	10/2/12
462	State Government	Information Security Officer	25	3.5	16	23:11:13	2/18/10	9/19/12
493	Financial Services	Senior Security Analyst/Team Lead	22	4.5	10	10:44:28	2/9/10	9/25/12
499	State Government	Infrastructure Protection Planner	1	7.0	4	7:52:41	8/16/10	4/21/11

- Indirect recruitment by emailing calls for participation to senior IT managers via an alias "IAC Outreach Coordinator"; and
- Direct recruitment of organizations to host evaluations, with organization representatives contacting prospective participants through internal communications.

The last recruitment mechanism listed was the most effective. Generic calls for participation were, in large part, ineffective. It appears that, absent encouragement and support by a respected champion or manager, the target audience filtered out these calls. The general nature of the venue was implicit in the calls, with various locations booked in West Des Moines, Des Moines and Ames, Iowa, and those responding to the general calls were able to walk to the venue. In the general recruitment scenarios, multiple mid-day sessions were planned for Tuesdays, Wednesdays and Thursdays. Events arranged using the last recruitment mechanism were exclusive to the organization's employee population and held in conference rooms in their offices. Although setup logistics might have factored into a given hosting organization's considerations, it appeared that in general organizations preferred to schedule private evaluation events after the lunch hour.

Recruitment criteria for Independent Professionals were that 1. a prospective participant was an IT professional who is an IT Leader, 2. a qualified person should have had direct IT incident response involvement for at least one IT incident, and 3. a qualified person should have had past experience with evaluating business risks associated with an IT incident. Personnel management experience was not required. The time commitment involved performing one evaluation of up to 75 – 90 minutes in a single session.

In order to collate all survey results in a common chapter, the description of the actual professionals recruited for this group is provided in Chapter 6.

3.2.2 Stage A. Define Problem and User Group

3.2.2.1 Objectives and Methods

One objective of this stage was to define the research problem in a manner sufficiently structured so as to provide boundaries on the research space for Study Group participants, but without overly constraining their considerations. A second objective was to define the user community the visualization research was intended to serve, based on the following criteria:

1. A community interested in the research objectives;
2. The likelihood that qualified community members could be recruited for user-centered design activities; and
3. Size and accessibility of the user community.

3.2.2.2 Outcomes

Business impact visualization, as a topic of research, was intended to provide conceptual bridging support between technical resources (both human and application) and business leaders in order to improve awareness and understanding of security and compliance events, and to support decision-making for specified tasks.

Although the specific criteria for recruiting Study Group members has been described, a more general description might characterize the Study Group as a collection of experienced IT professionals who function as business leaders or are senior technical staff who interact with business leaders frequently, so those user group members engaged in communicating and understanding security and compliance events. Moreover, these members made relevant decisions or supported those who do.

3.2.3 Stage B. Understanding the Need

3.2.3.1 Objectives and Methods

The first direct contact between researcher and Study Group members took place in this stage, which had two objectives: first, to establish rapport, gather professional background information and elicit the nature of the members' current professional roles; and, second, to identify possible needs this research could investigate.

While exploring possible needs, participants were asked to articulate these in the form of tasks or business processes that could be enabled through visualization. In their book, Dix et al. state that an interactive system is intended to assist a user in achieving goals with respect to practical undertakings[26]. Dix defines tasks as "operations to manipulate the concepts of a domain" ([26],pg. 125). The authors further define a goal as "the desired output from a performed task" ([26],pg. 125). In a semi-structured interview setting, the intention was to elicit tasks and goals that the present research effort could investigate via visualization.

3.2.3.2 Outcomes

After executing this stage with the initial six members (IDs 166, 191, 270, 400, 462, 493), a fairly detailed collection of professional background and work environment data was collected. Along with the members' professional history, raw needs data were collected as well. The professional information in Table 3.2 comes from this data.

3.2.4 Stages C. and D. Analysis of Visualization Need and Develop a Catalog of Needs

3.2.4.1 Objectives and Methods

In these stages, interview tapes were reviewed and information transferred into text form. Concept patterns were extracted from these interviews by reviewing the audio files

and assembled text. The objective was to isolate viable visualization needs, which was consistent with the problem definition specified in Stage A (Section 3.2.2).

The method of extraction was simple lexical feature extraction, isolating concepts not mentioned by other participants and augmenting the description of concepts held in common. After extracting these distinct concepts, the next step was to craft a description of each concept, thus constructing a catalog of needs.

3.2.4.2 Outcomes

The data collected in Stage B yielded a variety of complex business challenges with the potential of being addressed, in part, through visualization. The catalog of challenge areas and their high-level descriptions can be found in Appendix B. These needs were sufficiently complex that no single research project could adequately address more than one of them.

3.2.5 Stages E. and F. Prioritizing the Needs and Analysis of Needs Priorities

3.2.5.1 Objectives and Methods

After identifying a collection of visualization problems, it was necessary to choose. If the needs identified were functional issues arising from a common business problem space, it might have been possible to address multiple needs in one research project. As the needs reflected broader problems, it was necessary to select only one. In either case, a selection had to be performed, thus resulting in the first stage of reducing the scope of the research to be performed. In order for this process to be consistent with the user-centered design philosophy, it was necessary to consult the Study Group. Beyond establishing the priority of needs, it was necessary to confirm that these visualization needs were identified and characterized with sufficient accuracy. Stage E was the first followup stage in the methodology.

A simple voting scheme was chosen to elicit members' input. The approach was to distribute the catalog of needs and ask each Study Group member to pick three. Beyond selecting three problem areas, Study Group members were asked to answer the following questions for each task selected:

- How would you rank the general importance of the task from 1 (low) to 10 (extremely)?
- How would you rank this task relative to the others you selected? (Ties are acceptable.)
- How is this task relevant to your organization today?
- How will this task be relevant to your organization in the future?
- Although this task may be new to your organization, would you be able and willing to answer questions related to the performance of this task?

The last question was posed because, while it was possible a member might vote for a need, the member might be unable or unwilling to assist. After having read the catalog, a participant could have been inspired by something they had not considered previously.

3.2.5.2 Outcomes

All six members responded to the request to vote. The respondents answered the previously listed questions as well.

The responses were analyzed from the perspective of the number of votes and their general importance, as well as relative rank. Responses to the questions about the current and future relevance of a task or need to organizations added an additional perspective to the numerical and ranking responses. The results for the top three needs can be found in Table 3.3.

Table 3.3: Top Three Needs

Need	**Votes**	**Avg. General Importance**	**Avg. Relative Rank**	**Ability & Willingness**
Incident Management	5	8.0	1.6	100%
Compliance Management	4	7.0	2.0	100%
Risk Management	2	9.5	1.0	100%

Although a number of other needs received at least two votes, "Risk Management" received the highest general importance score. The "Compliance Attestation Support" need, by contrast, received no votes; further, the Study Group member who proposed the idea found other needs more compelling. There were some needs that received a single vote, but the pertinent group member felt uncomfortable answering questions related to how the task was performed. Given the goal to return to group members in later stages, this unwillingness to answer related questions made those needs (i.e. "Problem Management," "Senior Leadership Decision Support") unusable for this research effort. One shortcoming of this data-collection mechanism was that group members did not answer the "ability and willingness" question for tasks they did not recommend for the study. This meant that it was unclear whether the one person who did not recommend "Incident Management" might be willing and able to discuss it nonetheless.

3.2.6 Stage G. Need/Task Selection

3.2.6.1 Objectives and Methods

After collecting a potentially diverse set of possible tasks, the selection process began. The original plan for this stage of the methodology was to select three needs/tasks for further investigation and implementation. This plan was formulated as part of the IRB

study proposal, which was submitted prior to executing any portion of this methodology. Having performed Stages A – D, it was clear that only one need/task should be chosen.

As an aid to the need selection process, a set of questions was used to evaluate each suggested task. These questions and the answers for the selected need can be found in the next subsection for this stage.

3.2.6.2 Outcomes

Incident Management was the need chosen after considering answers to the following questions for the other tasks. The questions and answers that follow are therefore related to Incident Management. The bolded questions were critical. A task would have been rejected if any these questions were answered negatively. If more than one need passed the critical questions, the task with the most desirable sets of responses would have been selected.

- Which decisions are relevant to the tasks and goals?
  - Attack impact on the business, resource allocation, mitigation options and mitigation option impact on business.
- **Are these decisions important?**
  - Quotes from Study Group responses from Stage E.
    - "This task is important because of the ongoing need for communication and correlation of incidents."
    - "Incidents do occur and we need to be able [to] respond effectively."
    - "Incident management is vital to our org. It is how we meet both effective security management goals and meet regulatory requirements."
    - "All business leaders [are] not aware of all incidents that occur or the potential impact on the organization."

    - "This function would provide much needed incident assessment information to be used in quickly directing agency response and priority."

- Are these decisions likely common among business sectors in the U.S.?
    - Absolutely.
- **Are the participants able and willing to provide task analysis support for the task?**
    - Yes, there are at least five group members willing to assist.
- **Do participants consider this task important?**
    - Yes, this task is important in both absolute and relative terms.
- How unique is the task relative to the others suggested?
    - Given only the broadest understanding of these tasks, there are some similarities to Compliance Management and Risk Management.
- Can the task be subsumed by another task?
    - No, the dynamics between Incident Management and Compliance Management, as well as Risk Management, are somewhat similar; however, timeliness is a critical aspect of Incident Management.
- **Does the task now have enough definition to be investigated further?**
    - Yes, Incident Management appears to be sufficiently defined.
- Would its inclusion meaningfully add to the coverage of the business impact visualization problem space?

  - Yes, Incident Management appears to be important to nearly all group members. Time constraints on decision-makers enhance the value that business impact visualization can offer if an effective visualization approach can be constructed.

- **Does the task have a reasonable chance of being successfully supported through visualization?**

  - Yes. Nothing about the Incident Management problems would indicate that visualization would be inherently intractable to design or use.

3.2.7 Stage H. Understanding Selected Task

3.2.7.1 Objectives and Methods

The objective of this step was to explore how the selected task would be, or was being, accomplished by the participants' organizations. Several task-analysis approaches were explored, including those with a cognitive orientation such as Critical Decision Making (CDM)[29], Applied Cognitive Task Analysis (ACTA)[30] and the unnamed approach taken by Pfautz and Roth[31], as well as approaches such as Hierarchical Task Analysis (HTA) and Task Analysis for Knowledge Description (TAKD)[43][44]. There were many challenges related to eliciting knowledge, and by adopting a credible, established method some of these challenges were avoided or at least minimized. Tacit knowledge, as described by Polanyi[45], was a key consideration as participants expressed their understanding of the challenges, goals, contributing decision factors and situational context. Klein attempts to address tacit knowledge as well as perceptual learning in CDM.

The combination of semi-structured interviewing with a conceptual mapping approach was taken, incorporating one or more documented task-analysis approaches. The implemented approach drew heavily from "Working minds: a practitioner's guide to cognitive task analysis"[32], as well as [27][29][30][31]. Selected questions used in the

semi-structured interviews were taken directly from these works. The concept-mapping session execution approach was strongly influenced by Crandall et al.[32] as well as the technical report written by Novak and Cañas[46].

Thorough execution of an existing approach was complicated by the number of researchers needed, level of training necessary for implementing the approach, rigor of the output, level of useful detail, time costs and expense. Given the practical constraints of training, time and personnel, the objective of the research methodology was to capture the spirit of the selected amalgam of documented approaches.

The objectives of the knowledge and decision process elicitation phase in this stage resulted in identifying incident classes, incident management expertise, incident management roles, challenges, incident frequency, information needs, the pros and cons of leadership incident management involvement, motivations related to incident management, and the exploration of challenging incidents. No existing system provided incident management visualization, so participants were unable to express their needs at a functional level. Therefore, the more external or behavioral aspects of task analysis regarding activity lists, visual element design, necessary affordances, and current interface pitfalls were not ascertainable at this stage of the research.

3.2.7.2 Outcomes

All seven Study Group members participated in this stage, yielding a significant amount of input. Twenty-three sessions were held among the seven members, resulting in over 27 hours of recorded discussion.

Concept mapping was performed only with those participants who had the time, inclination and expertise to explore "focusing questions." Although some focusing questions were planned in advance, most came primarily from the first semi-structured interview sessions. A concept map was constructed interactively between a group member and the researcher. After the concepts were nearly complete, with ideas and relations explicit,

the researcher worked independently to clean up the visual layout and any apparent logical inconsistencies. The member who provided the input reviewed the map. One map was put aside after it became apparent that it was too employer-specific. The focusing questions explored were, "What is a security incident?," "How does a leader influence their interest/involvement thresholds?," and "How does integrated incident management function?" Beyond distributing the resulting maps to the group, no session time was devoted to eliciting feedback from group members other than their authors. Unfortunately, the dimensions of these maps are not conducive to this document's format restrictions, and therefore have not been included.

3.2.8 Stage I. Analysis of Task Exploration

3.2.8.1 Objectives and Methods

The objective of this stage was to integrate the ideas shared by group members in Stage H and to synthesize a firm understanding of IT Incident Management based on the varied responses to the elicitation probes. In order to achieve this understanding, observations were gleaned from multiple passes through the group member input. Observations were sorted into "Ideas," "Decisions" and "Notions." Ideas were observations participants made in the course of performing their roles as IT incident responders. Decisions were choices or judgments that leaders made during an IT incident. Notions were beliefs regarding IT incident management that resulted from direct statements by one or more participants, or logical patterns resulting from reviewing participant input and integrating it with knowledge of the subject matter.

3.2.8.2 Outcomes

Working documentation developed over this stage collected more than 325 Ideas, more than 90 Decisions and more than 100 Notions. After exploring logical relations between the Notions, it was determined that Notions could be assembled into nuanced

perceptions of IT incident management called "Principles." In some cases a Notion was sufficiently significant to merit membership in the Principles category on its own. Ideally, members in each category were sufficiently refined so as to be distinct, but in fact there may be inflation in these. Duplication was erroneous in certain cases, but some members were kept distinct in order to preserve nuance. A sample of each analysis category is provided in Appendix C to assist in understanding the outcomes of this stage.

3.2.9 Stage J. Identify Actors & Dynamics

3.2.9.1 Objectives and Methods

A common practice in user-centered design is to identify the actors who will be affected directly or indirectly by the intended system[27][26]. Having identified the actors, the next step is to develop profiles for them. Having developed a context for the actors, the final step is to understand the activities and objectives of the actors[32]. These analysis activities are part of the overall task-analysis process.

After analyzing the output from Stage H, a number of actors were identified. The concept mapping and interview responses provided insights that allowed the task structures within IT incident management to be identified and expressed in graphical layouts. A holistic "swim lane" flowchart was developed to provide a broad overview of the IT incident-handling lifecycle. IT incident management today is a communications and coordination effort that is all but manual or enabled by communication technology with limited integration with information systems. The few information systems that are relevant are isolated and commonly serve only one actor class (e.g. network health monitoring, security event monitoring). Due to the lack of a functioning platform on which group members have experienced IT incident management tasks being performed, it was necessary to superimpose tasks on a conceptual placeholder. Hierarchical Task Analysis was used to lay out the task structures or task hierarchies and describe activity patterns within those task hierarchies with plans[26].

3.2.9.2 Outcomes

Actors

As shown in Figure 3.2, a variety of roles were identified that have at least a selective interest in the awareness of incident particulars. There were essentially five core roles to IT incident management that became the focus of this visualization. These roles are the "Incident Coordinator", "Incident Response Team Member", "IT Leader", "Business Leader" and "Stakeholder". Beyond the roles within the inner core were those users potentially affected by the incident in terms of disruptions or the unintended disclosure of sensitive information. External parties were those entities having statutory, regulatory or contractual obligations to know about classes of incidents. Given the broad range of possible external parties, business relationships and classes of possible incidents, it is reasonable to consider some of these entities as possible stakeholders on a per incident basis. Internal affected users were considered to be potential stakeholders on a case-by-case basis. The key difference between a stakeholder and an external party was that the organization had an expectation of controlled secondary disclosure. In other words, the organization could expect that, without formal approval, the details of the incident would not be shared beyond direct external party participants.

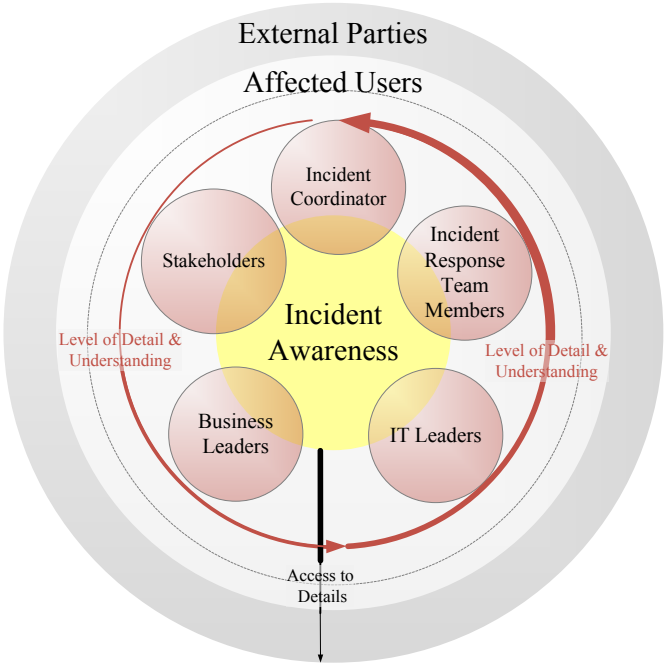


Figure 3.2: Incident Awareness Among Actors

Communication with affected users and external parties was conducted through controlled means and included liaisons, public relations specialists and managers. Other than being a possible source of information for designated intermediaries, data provided by the visualization was not expected to be accessible to affected users and external parties.

Incident Coordinator

The Incident Coordinator is responsible for the timely investigation and restoration of normal operations of the affected systems. Timeliness was a somewhat subjective parameter, given the complexities of determining incident impact and cost. Nonetheless, whatever priority level an incident had been assigned, the Incident Coordinator was responsible for meeting that expectation.

The "Event Coordinator", not depicted in Figure 3.2, is a similar role that performs

external communications and coordination activities with respect to the response team. This may be potentially either a dedicated role assigned to a designated person or the related duties are incorporated among the responsibilities of the Incident Coordinator. The Event Coordinator role was determined to need a current and nearly as complete an understanding of the incident as the Incident Coordinator, because the Event Coordinator was primarily responsible for communications and resource coordination with Business and IT Leaders, "completeness" in this sense was more a description of breadth than depth of technical understanding.

The background of the Incident Coordinator varied by organization and incident. In certain organizations an Incident Coordinator was a senior subject matter expert who specialized in networks, applications, databases, storage, servers or security. Though having no management authority, these technical Incident Coordinators were nonetheless typically empowered to involve any other technical person within an organizational unit. Some organizations have IT directors take charge of incident coordination upon designation of an event as an incident, and yet others transfer coordination as an escalation procedure. A managerial coordinator often relies heavily on senior subject matter experts to provide technical advice and interpretation of incident particulars, as the centralized incident management approach results in these managers being responsible for a full range of incident types related to operations, security and compliance.

Responsibility for incident coordination was commonly associated with operational ownership of the affected system. If a senior technician or IT director was responsible for a system's operations, then any incident related to that system was their responsibility.

Information security incidents were possible exceptions in organizations with a less unified incident management framework. Information security was a concern that cut vertically from business operations down to bits on the wire. Further, a security incident often has a historical dimension, in that a previously unknown incident may have been initiated months or even years ago, and potential malicious activity may be current or

may have ceased. Malicious intent was not a prerequisite for a security incident. Impact upon or risk related to the confidentiality, integrity or availability of information in or on all forms of media and information-handling components fell within the scope of information security. Dedicated security personnel typically addressed these wide-ranging incidents.

Incident Response Team Members

Team members came from a wide range of backgrounds. The response team consisted of people who had competency or expertise in various technologies and business processes affected by the incident. Members could be service provider employees or contractors who were either already on site or called in specifically for the incident. The team could be geographically dispersed by being separated by floor, or in different buildings, cities, states or even countries.

Service provider members and other vendors who were not physically present on organizational property were commonly secondary members of the team, since many times there was little transparency to their activities, priorities and knowledge. It was probably safe to assume that the reverse was true as well. The organization would treat these members more like external parties than trusted core participants.

Responsibilities of the primary team included technical activities such as troubleshooting infrastructure components, root cause analysis, software fixes, computer forensics and application administration. Less technical activities included obtaining signed agreements, business process reviews, contract discussions and collecting supporting documentation. Incident particulars drove the need for the type and level of expertise needed, as well as determining the nature of the activities team members performed.

IT Leaders

IT Leaders came from a variety of educational and professional backgrounds. Front-line managers direct technical staff, ensuring projects are completed within acceptable timeframes and quality standards, and many are responsible for the availability and operational integrity of the platforms entrusted to them. As one participant put it, these managers "keep the wheels on the bus." It was uncertain whether a common level of understanding of technical details could be expected from frontline managers. Ideally, they had a conceptual model not only of the contributions the systems under their care made to their particular organizational unit, but also to the organization overall.

Continuous change in technologies and architectures raises significant challenges for leaders to maintain some level of technical mastery as they distance themselves from technology design and operations with each move up the leadership hierarchy. Middle and upper managers in the IT organizational structure were less in touch with technical knowledge, and were progressively more focused on strategic challenges. As incidents become more severe in impact, escalation procedures commonly dictate that upper-level managers take responsibility for making decisions with progressively greater risk to operations and/or recovery costs. In some respects this approach matches responsibility with pay grade, as well as taking advantage of an organizational worldview that is better aligned to negotiate between potentially conflicting business objectives or demands. In addition to its technical complexity, there was a real possibility that an incident that had escalated might represent significant uncertainty in terms of root cause and time to repair. One participant raised the point that well-known or straightforward incidents are dealt with confidently, and typically with little if any escalation. A possible exception was when the scope of impact was large, but the root cause had been readily identified and recovery expedited. For example, a power outage to an office building may result in the loss of climate controls and worker productivity. In this case, after assuring personal

safety and data center operations, the incident response is primarily a matter of patience and communication with the service provider. Poor disaster planning may require service triage in order to conserve the backup power supply.

The IT Leader's role within incident management was varied. Some organizations had IT Leaders directing response on site, while others had leaders external to response efforts authorizing actions, allocation of resources, direct costs, appointment of the Incident Coordinator and communications with affected business units. IT Leaders were responsible for setting priorities or complying with priorities set by upper management.

Business Leaders

Business Leaders, understandably, were focused on their businesses. Unlike IT Leaders, who are familiar with the causes of operational failure and deal with incidents routinely, Business Leaders may never be involved with IT-related incidents. Any given incident they were consulted on might have been their first in a very long time, if ever. Simply put, IT-related incidents were not on their radar. Incidents escalating to the point of Business Leader involvement were not just serious disruptions to processes, depending upon the affected systems, but awareness of and participation in the incidents could potentially disrupt a significant portion of the Business Leader's day(s).

Given Business Leaders' responsibilities and motivations, awareness of and involvement in an IT-related incident must be absolutely relevant to them and their purposes. Interest was commonly limited to impact, length of time to repair and resumption of services. Often, impact was something Business Leaders assessed and conveyed to the incident response team, as only they fully understood the value an affected system had to the business. Their involvement may be sought in order for incident response plans and possibly costs to be authorized. Also, they may be asked directly or indirectly to contribute to any prioritization evaluation taking place within or between active inci-

dents.

Stakeholders

The business function of persons in this category cannot be narrowly defined. In certain respects, some stakeholders walked a fine line between wanting to be aware of an incident and not caring much more than a typically affected user. Stakeholders were not commonly asked to be involved directly, but often attempted to maintain awareness of the incident. Incident awareness helped stakeholders anticipate impacts on their responsibilities as a result of the incident. As the incident evolves and response progresses, the incident may affect interdependencies of direct concern to the stakeholder. Depending on interest and needs, a stakeholder may want access to the complete portfolio constructed for an incident. Compared to the rest of the core set of incident awareness participants, stakeholder access to information in terms of detail and update frequency was not nearly as compelling.

Affected Users

There were several classes of affected users, including customers who relied on offered services; customers whose information was held by the organization; the general public accessing public information resources; internal staff directly responsible for generating revenue through sales, manufacturing, order fulfillment or providing billable services; and internal staff who in some manner supported business operations. The class of affected user(s) contributed to the assessment of an incident's impact.

These users were kept distant from incident response, as organizations typically restrict the release of information on a need-to-know basis. The timing of their awareness was contingent on establishment of a concrete understanding of incident details relevant

to a particular user class. Data breach notification timeframes, as well as the content and methods of communication, were based upon adherence to statutory and regulatory requirements. Business Leaders or IT Leaders informed internal users with details such as the systems affected, loss or degradation of functionality, and time to repair.

External Parties

External parties consisted of numerous relevant entities based on attributes such as class of organization (e.g. Securities and Exchange Commission (SEC) and publicly traded companies), business sector, and accepted methods of payment (e.g. Payment Card Industry (PCI) and e-commerce sites), as well as the nature of the incident. In governmental organizations, security incidents were reported to a Computer Security Incident Response Team (CSIRT), and possibly to a Chief Information Security Officer (CISO) with broad oversight requirements. Law enforcement was initially external, but could potentially become much more integral to the response. Business partnership negotiations dictated when and how much involvement was needed by a business partner for a particular class of incidents.

Since communications regarding incidents were often difficult, legally awkward and even embarrassing, the inclination was not to disclose incidents, regardless of whether the incident had been resolved or was historical. However, statutes, regulations and, possibly, legally binding contracts required the organization to overcome its desire for privacy and communicate to outside entities. The questions of when, how, what and to whom to communicate information were commonly answered by those specializing in compliance. In some cases, the person responsible for communicating with an external party was designated prior to an incident. And in many cases, communications with external parties required legal consultation in order to ensure a proper interpretation of the applicable legal language, and to minimize the potential exposure to liability from

communicating too much information.

Dynamics

The flow chart provided in Appendix D addresses the high-level interaction among the five core response team roles. The symbols used are those of traditional flow-charting. The flow of response activities is not always toward closure of the IT incident, as there are circumstances that require the return to a previously completed task. To assist with making flow in the "forward" direction easier to distinguish from "backward" flow, the backward flow indicators are drawn with dashed lines. Activities that straddle swim lanes are potentially collaborative activities between the actors designated in those lanes. The IT incident management processes across organizations appeared to have much in common, but each organization adopted a process that had unique elements. The flow diagram is an attempt to provide a fairly generic representation of IT incident management. When fielded, a viable visualization solution would need sufficient flexibility to accommodate differences in workflow.

A number of task structures were developed superimposing the concepts identified in Stage I (Section 3.2.8) onto a yet-to-be-designed visualization system. The process of identifying tasks was in part influenced by the requirements being drafted in Stages K (Section 3.2.10) and M (Section 3.2.12). Performance of this stage (i.e. Stage J) did not stop until Stage P (Section 3.2.14). Task structure diagrams were constructed for the following tasks:

- Get started
- Achieve general awareness of business
- Achieve updated awareness of incidents
- Achieve updated awareness of a specified incident

- Achieve general awareness of business and explore an incident's details
- Achieve updated awareness of incidents and explore an incident's details
- Achieve updated awareness of a specified incident and explore the incident's details
- Achieve updated awareness of incident and identify assigned tasks
- Perform decision/judgment task
- Achieve updated awareness and report on task status and outcomes
- Achieve updated awareness of incident while responding to notification
- Achieve updated awareness of incident and determine priority changes in assigned tasks
- Incident assessment: cause, symptoms, time sequence of events, impact, measurement, consequences, unknowns, responsible parties
- Response plan selection and approval
- Response resource acquisition
- Response role management
- Response resource tasking
- Response monitoring and logistical issue awareness
- Awareness monitoring and management
- Escalation monitoring and management
- Incident management improvement
- Control change evaluation

- Incident introduction
- User-directed communication

The tasks were structured from the perspective of the actors, namely Incident Coordinator, IT Leader and Business Leader. A sample of task structure diagrams is provided in Appendix D.

3.2.10 Stage K. Identify Requirements

3.2.10.1 Objectives and Methods

Requirements bridged the conceptual divide between the IT incident management problem space and the tangible visualization system. While post-processing the interactions with group members, there was an opportunity to gather rough ideas that contributed to the requirements development process. The initial objective of this stage was not so much to formulate fully refined requirements language as to throw a wide net around the comments, ideas and thoughts these conversations provoked during post-processing.

Having collected the raw set of preliminary requirements, an intense refinement process began. One thing to note is that group members were not necessarily software or visualization designers, and that the conversations in Stage H (Section 3.2.7) were not designed to elicit requirements directly. While constructing the set of requirements, it was necessary to integrate input from relevant visualization research[15][47][48] and other authorities.

Designing a system required making choices. When choices were a matter of addressing one requirement at the expense of another, it was necessary to establish an explicit priority. A truly user-centered design approach depended upon the users themselves to dictate priority. A formal requirements ranking methodology was utilized to capture an objective and consistent ranking of requirements. Formal ranking systems

such as conjoint analysis[49] and Analytical Hierarchical Process (AHP)[40] are plagued by scalability issues. Both require pairwise comparisons, which translates to $(N \times N - 1)$ comparisons. To illustrate this problem, when considering the evaluation of ten requirements, we find that ninety comparisons need to be made. Further, abstract conceptual requirements anticipated for this visualization were more difficult to compare than requirements or attributes for which one has an experiential understanding (e.g., "Do you prefer the flavor of oranges or apples?"). As the cognitive load placed on a group member needed to be minimized in order to avoid frustration and produce valid feedback, the number of requirements formulated had to be manageable.

This requirements design constraint raised the challenge of how best to structure the requirements and designate the level of generality. Broadly described general requirements covered more design space, but typically were not actionable at the developer level. Moreover, broad language had a greater risk of comprehension errors and interpretation inconsistencies across group members. The alternative was a set of requirements written with precise, even "granular" language that covered a narrow partition of the design space. To compensate for this lack of coverage, quantity quickly escalated. A compromise was needed. AHP allows for requirements to be posed in a hierarchical fashion. By leveraging the hierarchy, one could isolate more granular requirements into subsets, thus reducing the number of pairwise comparisons, and still get the conceptual clarity needed for high-level design.

3.2.10.2 Outcomes

The initial round of unrefined requirements yielded 85 preliminary requirements, and consolidating those yielded 65 intermediate requirements. The 65 requirements were clearly too many for any group member to rank, so a more philosophical approach was taken. A set of broader, high-level requirements that addressed the conceptual dimensions of the visualization was drafted. Given this broad scope, a second round of

supportive requirements was needed to provide guidance for the high-level design phase. Leveraging the hierarchy between these two levels of requirements definition appeared to be a reasonable compromise between quantity and level of effort for the group members. The requirements in their final form are provided in Appendix E.

3.2.11 Stage L. Review & Influence Requirements & Understanding

3.2.11.1 Objectives and Methods

This stage represented a vital followup activity. Having processed all the various inputs, it was necessary to share what was learned from the "Understanding Selected Task" stage. The researcher first needed to verify whether the resulting synthesis tracked with reality. Moreover, the requirements resulting from the analysis needed to be validated, corrected and supplemented, if necessary. A second objective was to discuss the interpretation and intention of each requirement. The parsing and interpretation of language is subject to contextual and subjective understanding. In order for the requirements prioritization to be useful, then, each responding group member needed to interpret each requirement consistently.

Another key objective of this stage was to inform the group members of the change in research scope. Analysis to this point yielded three actors who were leaders and would benefit from a visualization system. Up to this point, the group members knew only that the research scope had been limited to IT incident management.

3.2.11.2 Outcomes

Five group members were available for followup sessions and the upcoming requirements prioritization activity in Stage N (Section 3.2.12). Overall, feedback on the broad understanding of the nature, actors and challenges of IT incident management was positive. The discussions tended to explore the various observations a bit further, based on what resonated with a given group member at the time.

Several suggestions regarding requirements language were made. In a couple of cases, the requirements discussion yielded new features (e.g. 1.C Report, 4.D Response Role Management, 4.E Timeline and Dependency Awareness) and isolated aspects of others (e.g. 3.B Interactive Internal Users, 3.D Passive Non-Core Actors), thereby yielding new requirements. The group members did not identify any requirement as superfluous, a fact participant 493 stated explicitly. The requirements in their post-revision form are provided in Appendix E.

3.2.12 Stage M. Revise Requirements and N. Prioritize Requirements

3.2.12.1 Objectives and Methods

With only one requirements review and discussion iteration, revising and adding requirements during Stage M was challenging. It was necessary to incorporate the insights of the group and care was needed with language revision to avoid diverging too far from the original intentions discussed with group members. Both requirements labels and requirements definitions were changed. The primary basis for changing a requirement's label was that the original label inadequately conveyed the requirement's objective. Requirement feedback that narrowed the scope of an original requirement tended to introduce new requirements in order to preserve the design space coverage. New features also yielded new requirements. As a consequence of these changes, new requirements increased the effort group members would invest in the prioritization process. Another consideration was that, whatever the cause for a new requirement, group members would see them for the first time during the ranking exercise. The risk of comprehension misalignment was naturally higher, so the potential benefits of the requirements had to outweigh the dissonance that inconsistent comprehension might introduce.

Those Study Group members who participated in Stage L (Section 3.2.11) were asked to perform the prioritization process. It was necessary that each participant review the requirements language and context with the researcher before prioritization.

The requirements prioritization followup process was based on AHP[40]. Each group member performed the pairwise comparisons at their own pace and as their schedule permitted. This meant that a group member could spread the effort over several prioritization sessions. Researcher involvement was limited to providing prioritization materials, checking on status and collecting the prioritization forms. The materials sent consisted of the revised requirements and the instruction and prioritization forms found in Appendix F.

The leadership actor classes of Incident Coordinator, IT Leader and Business Leader were identified as viable targets of this research, and the prioritization process was structured to accommodate any differences in needs among them. At the risk of statistical shortcomings within the results, group members were asked to rank requirements based on an assigned leadership role. Leadership assignment was based on each group member's professional experience. Furthermore, explicitly setting the assumed role was meant to clarify the context in which a group member should evaluate the pairwise options.

The analysis plan was to use the resulting preference value for each first-level requirement to weight the subordinate (i.e. second-level) requirements' preference values. This allowed all second-level requirements to be ranked relative to one another, and avoided group members having to rank all second-level requirements directly (i.e. 190 pairwise comparisons as opposed to 1332). This approach also provided greater insight into the relative priority of the broad features (i.e. first-level requirements) and the capabilities most needed by the leadership role.

3.2.12.2 Outcomes

The five group members who participated in Stage M participated in Stage N as well, with the following role assignments: the Incident Coordinator was represented by participants 166 and 462, the IT Leader by 400 and 493, and the Business Leader by 191.

In order to compute AHP-preference values, consistency index and consistency ratio the program Matlab was used. In addition, MS Excel was used to prepare reciprocal matrices and input patterns for Matlab, as well as to facilitate results analysis.

The consistency index and ratio created as part of the AHP computations showed that some participants had trouble being logically consistent with their responses. Logical consistency is a concept independent of variance. Logical consistency tells us that when A is ranked higher than B, and B is ranked higher than C, then it would be logically inconsistent to rank C higher than A. Such inconsistency occurs frequently, according to various authors. Saaty, developer of the AHP method, recommends that a consistency ratio of 0.10 be accepted as indicative of good logical consistency[40]. Karlsson suggests that a much higher but unspecified ratio is common in practical evaluation contexts, particularly with software requirements ranking[41][42].

A noticeable improvement of consistency was seen when ranking judgments were aggregated across multiple group members. Aggregation of ranking was done using a geometric mean, as recommended by Saaty. Aggregated ranking inputs were then processed through the AHP method instead of attempting to average the AHP results for each respondent. The averaged ranking across all five group members provided an exceptional level of consistency. The rankings computed from the input of all five group members was designated the "Overall Leader," which was treated as a composite of the Incident Coordinator, IT Leader and Business Leader roles. The leader-based aggregations (e.g. average of two IT Leader inputs) showed an improved consistency, but typically not the same level of improvement seen when using the averaged ranking across all five ranking responses (i.e. "Overall Leader").

The Business Leader rankings were less logically consistent, given individual idiosyncrasies and the lack of additional Business Leader respondents to help yield greater consistency. The logical consistency ratios for the Business Leader ranged from 0.1059 to 0.3404. (Rankings were considered acceptable if the consistency ratio was 0.35 or lower.)

Frankly, it was difficult to remove even the most inconsistent inputs across leader roles, given the weaknesses associated with such small samples (e.g., one consistency ratio was as high as 1.4). One exception was seen in the IT Leader ranking of "Incident Handling Documentation" sub-requirements, with a ratio of 0.5053. This ratio was influenced by the previously mentioned inconsistency represented by a ratio of 1.4. Possible reasons for high ratios included poor appreciation for the requirements being ranked, fatigue and attempts to voice preferences emphatically, thus causing imbalance in the ranking values.

The ranked listings by leadership role, as well as the second-level requirements, can be found in Appendix G. The results are ranked from lowest to highest.

3.2.13 Stage O. Interpret Requirement Priorities

3.2.13.1 Objectives and Methods

The objective of this stage was to glean coherent and reliable guidance from the prioritization results, which turned out to be challenging. Beyond the reliability issues of consistent requirements interpretation, group member logical consistency, and small leader-role sample sizes, there was the challenge of interpreting the numbers. It was clear that one requirement had been ranked higher than another, but how does a ranked list provide guidance?

Other than for the Business Leader, requirement priority interpretation was performed on the aggregate inputs collected for the IT Leader, Incident Coordinator, and Overall Leader perspectives. Even with that determined, however, AHP results interpretation was nonetheless challenging. For someone with a more holistic and forward-looking view of how incident management visualization might be used, some choices appeared to be odd. This observation has less to do with those exceptionally high-ranked requirements than for those requirements given such a low preference rate that one might infer their exclusion or dismissal. But, given that these requirements were not rejected or combined during the requirements review discussions, one could not conclude that re-

quirements priority results advocated their exclusion. The current "state of the art" may have stifled imagination, or it may have been difficult for a group member to extrapolate value from a given feature without any experience with it in current solutions. For example, in the 1970s, would the fact that in 2011 the number of emails sent over the Internet surpassed letters sent through the U.S. postal system have been widely considered?

Nonetheless, the preference results did indicate the relative added value that each requirement provided, both overall and to leader types in particular. On this basis, then, it was decided that, based on their ranking, prioritization results would drive design emphasis and focus.

The rest of this section discusses the approaches explored in order to interpret the significance of the AHP results. Before proceeding, though, it is worth considering that questions such as "Why were particular choices made?," or "What message should be extracted from members' preferences?," risk drawing false conclusions. The data may support a given interpretation with which the participants may very well disagree, based upon a much simpler motivation. For example, one could imagine a response such as, "I had an hour to spend on the ranking, and my answers made sense to me at the time."

Kano Quality

A product quality model proposed by Kano Noriaki (the "Kano Model") categorizes requirements or product features/qualities in terms of customer satisfaction. Zultner suggests that the Kano Model has three types of user requirements: expected, normal and exciting[50].

- Expected Requirements: Features a user expects, meet but do not exceed expectations. The lack of these features or their poor implementation would be very vexing.

- Normal Requirements: Features desired that achieve user satisfaction in relation to the degree to which they are instantiated.

- Exciting Requirements: Features that astonish users and are very pleasing when available and enacted deftly. Since these features are unexpected, there is no risk of discontent if they are not present. Their successful implementation are often what sets the product apart from the competition.

The Kano Model was considered a potential lens through which to interpret the preferences voiced by participants. Low-priority items would simply be interpreted as "expected" and those more widely preferred as "exciting." In between, the requirements would likely be labeled "normal." Given the uniqueness of this visualization effort, there was relatively little found to be "normal." The most appropriate comparison was between the visualization and the isolated processes performed today. Clearly, the visualization must perform as well as current processes, and would be disappointing were it not superior to current efforts.

One simple method was to assign Kano designations to each requirement by dividing the requirements into three subsets of roughly equal cardinality based on preference weights. This assumed that the rationale behind the weights was a matter of expectation, and that bucket sizes for the Kano categories would be roughly equal. This interpretive method did not appear to consider that any practical solution that might replace or minimize reliance on current isolated IT incident management processes would necessarily be welcomed. The proverbial bar could be fairly low, thus setting expectations fairly low in general. With expectations low, a large portion of the requirements would fall into the "exciting" category, thereby losing the distinctions desirable for effective requirements prioritization. As for the preference weights, the AHP comparison criterion specified was for the participant to rank by importance, which could be interpreted to mean relevance. Applying the Kano Model to the requirement priorities was helpful but not sufficient.

Requirement Dependencies

Ideally, requirements should be constructed to be independent of – and therefore possibly substitutes for – each other. For example, an automobile needs a source of propulsion, which is a dependency. Within an automobile's use case there are potentially multiple independent substitutes available, such as a four-cylinder gasoline engine, six-cylinder diesel engine, hybrid, all electric or fuel cell. Although hybrid, all-electric and fuel-cell propulsion have common elements such as an electric motor, these approaches are positioned in the automotive industry as substitutes. Requirements developed for the visualization could be viewed as a progression of added value, with many requirements dependent on or interdependent with each other. These dependencies were based on software design principles as well as the progressive nature of a user's cognitive and functional needs within IT incident management. A non-monolithic network protocol stack such as TCP/IP is both conceived and implemented as a progression of network services. Protocol layers have both interfaces that provide value directly to the user as well as those upon which other layers within the stack depend to add their own value.

By articulating requirements as a progression, an evaluator and designer could see how some of the more elaborate features and use cases came into being. This, however, muddies the ranking evaluation and interpretation of results. A lower-ranked requirement may not be directly relevant to a leader, but without it features of interest will not function properly. Another interpretation of the prioritization could be that a group member may not have been able to envision a particular feature's function without relevant dependencies and, wishing to ensure their inclusion, therefore inflated a requirement's *direct user value* (DUV), i.e., the benefit a requirement provides to the user firsthand. There were many potential nuances considered when interpreting the preference weight a group member assigned to a requirement. The interpretive assumption established was that

group members ranked requirements based on the importance of a requirement's DUV to their AHP comparison context.

Distribution of Preference

Another approach to gaining insight and direction from the requirement ranking results was to order by rank the sub-requirements for the purpose of analyzing the distribution of preference by leader type. This was performed by accumulating the preference weight, starting with the sub-requirement with the highest weight, then adding the corresponding descending preference weights for each of the sub-requirements until a cutoff threshold was reached. Those sub-requirements in the ranked list falling after the threshold was reached were excluded from the set of preferred sub-requirements for that threshold. The converse was true, in that sub-requirements "accumulated" prior to the cutoff were in the preferred sub-requirements set. The threshold was then varied in order to observe the corresponding preferred sub-requirements set. The amount of sub-requirement rejection is inversely proportional to the threshold. The preferred sub-requirement set for a threshold of 65% will have fewer requirements than for a threshold of 90%. Choosing a threshold was challenging, because an overly restrictive set could result in an unworkable or uninteresting visualization design from the perspective of the user community. A complementary challenge was that a high threshold did not discriminate as to preference, and therefore was counterproductive with respect to obtaining guidance and insight.

In order to make analysis manageable, thresholds of 65%, 70%, 75%, 80% and 90% were analyzed. As one would expect, nearly all sub-requirements fall within the first 90% of accumulated preference weight. Not only was there interest in understanding the needs of the three leader roles, it was also important to understand needs that were common across leader types. Such knowledge could potentially assist the researcher in

understanding both the degree and form that requirements should take in the role-based interfaces. One possibility was that there would be so much in common that role-tailored interfaces were unnecessary. The Venn diagram provided a convenient organizing structure with which to analyze these interrelations.

Interpretation through Consolidated Lenses

None of the dimensions or lenses of interpretation mentioned were sufficient for use on their own; however, a combination of these provided a rational interpretation. From the outset it was clear that the visualization needs for an Incident Coordinator, IT Leader and Business Leader were not the same (see preference values in Appendix G). An effective visualization would need to be tailored to the user's incident response role. Another important observation was that, once manifested, not all requirements would be directly manipulated by or even visible to the user. These were called "contextual requirements." For example, the sub-requirement "3.A Intra Core" speaks to the need for the core response actors, described earlier in Stage J (Section 3.2.9), to be able to communicate with one another through the visualization. This requirement was more relevant to a use-case or operational context than to an actual communication mechanism the user would employ in order to effectively communicate. The use-case or contextual requirements were essentially a second class of sub-requirements. In this visualization research, the most relevant requirements were those that yielded features that were seen and/or interacted with. These were called "visible requirements."

The interpretive dimensions were integrated by applying the distribution-of-preference lens, followed by requirement dependency and then Kano Quality. The first lens acted as a filter that allowed the group members' preference weights to dictate those requirements to be excluded. Due to requirement dependencies and basic expectations, the strict application of a user-based weighting exclusion would have resulted in an inadequate so-

lution. The requirement dependency and Kano Quality lenses provided opportunities to iterate through the "excluded" requirements and restore them based on the rationale of requirement dependency and expectation.

In order to apply the preference distribution lens, a threshold had to be chosen. The threshold could not be chosen based on an arbitrary numerical selection, but instead only after reviewing the composition of the resulting "included" requirement sets for each of the leadership roles. Group members were not asked to evaluate the requirements as "contextual" or "visible"; however, interpreting their preferences required these attributes to be considered. Those requirements considered to be primarily contextual displaced "visible" requirements within the preference weight distribution. This displacement could possibly have sharpened the focus on those visible requirements falling within a chosen threshold, but this focus may not be representative of the broader population of leaders in these roles. The weighting was done only by two people at most per leadership type.

A looser focus was considered for the sake of appealing to an audience broader than the Study Group. In order to loosen focus, contextual requirements falling within the chosen threshold were discounted. When choosing a threshold, it appeared to be prudent to include 55% – 75% of all visible requirements on considering the union of visible requirements preferred by the Incident Coordinator, Business Leader, IT Leader and Overall Leader. In order to further refine the threshold selection process, the percentage of visible requirements by leader type was also considered. A visible requirements coverage of less than 35% per leader role was considered too restrictive. However, the primary rationale for this lens was to exclude sub-requirements, so thresholds in which each leader type's preferred requirements covered more than 35% and less than 55% of the visible requirements were good candidates. Picking the lowest threshold that met that criterion was considered a reasonable selection. The Overall Leader type exhibited the greatest consistency of judgment based upon an essentially averaged preference. The

Overall Leader's preferred visible requirements coverage was another good indicator for choosing a threshold. As previously mentioned, the 35% – 55% range of visible requirements was considered reasonable; thus, a good threshold would be one in which the Overall Leader's visible requirements selection fell in the middle of that range.

Having selected and applied the threshold, the included requirements were effectively established for both the visible and the contextual requirements. A review of these requirements was necessary to ensure that dependencies and expected requirements had not been discarded; if they were, then it was necessary to reintroduce them into the included list. This was done not to overstate the importance of necessary or expected requirements, but instead because, from a design and development requirements management perspective, basis requirements were necessary in order to justify resources needed to instantiate the substance of those requirements, thus providing a means for requirements traceability.

When developing evaluation tasks for the "Industry Public Evaluation" and high-profile visualization features, the preference weights and Kano Quality model were helpful. When one considered that the requirements prioritization method forced the group member to place one requirement over another in terms of value, there was essentially a limited preference budget. Those requirements with greatest weight were of greatest interest, one reason being that they were "exciting." This preference interpretation led the visualization design to feature those requirements, and guided definition of the evaluation tasks to ensure activities were crafted so that these features would be exercised by the evaluators.

3.2.13.2 Outcomes

The final outcome of applying the method described in "Interpretation of Consolidated Lenses" is listed in detail in Appendix I.

The threshold chosen was 70%. Two of several Venn diagrams used in the inter-

pretation analysis are provided in Appendix H. The 70% ranking threshold emphasized visible requirement count by leader role thusly: Incident Coordinator – 10 requirements (41.67%), IT Leader – 13 requirements (54.17%), Business Leader – 9 requirements (37.5%), Overall Leader – 11 requirements (45.83%). The 65% ranking was rejected as too restrictive for the Business Leader role (seven visible requirements, or 29.17%) and the Incident Coordinator role (eight visible requirements, or 33.33%). The 75% ranking threshold was rejected based primarily on the adequacy of the 70% threshold. In other words, additional relaxation of the priority interpretation was not necessary.

3.2.14 Stage P. Develop High-Level Designs

3.2.14.1 Objectives and Methods

The objective of this first design step was to construct a small collection of design alternatives in order to provide study participants the first concrete description of what the visualization would do to facilitate IT incident management.

The requirements priorities and resulting interpretation in previous stages provided the basis for the high-level designs, including the context for and constraints upon the brainstorming effort. This brainstorming effort was intended to generate design architectures with sufficient variation in order to be qualitatively different. The degree of difference was to be balanced between solution-space coverage and practical viability within the context of time and budget for this research. Design architecture was a broad specification that described technology components and their interactions, as well as usage dynamics related to executing selected tasks. This architecture was articulated from the user's perspective rather than from any description of the engineering necessary to facilitate visualization.

Each design alternative was to have an emerging conceptual model. A conceptual model is a user's mental representation of the operational features and behaviors of a device or system[51]. Norman argues that "[a] good conceptual model allows us to pre-

dict the effects of our actions" ([51],pg. 13). Further, Norman suggests that usability of an application improves when a user is able to establish an accurate conceptual model and the application behaves consistently with this model. The conceptual models were expected to be abstract at this design stage, but would become more concrete in the prototype stage. Although, as an emergent property, the conceptual model was consciously considered during design, it was not the result of any one design choice.

The expected work product from this research stage was a set of three design alternatives. Each alternative would consist of an overview, sketches and illustrations, as well as at least one usage scenario from the user's perspective that incorporated the selected tasks. These materials were to be provided to participants. As an informal means of self-assessment, each design was evaluated against the requirements prior to participant review. A comparison between the requirement priorities and participant feedback was expected to be of value for design decisions made in later stages.

3.2.14.2 Outcomes

This stage was the first in which the Industry Public Evaluation stage was highly influential in the design process. Along with understanding the IT incident management problem space and visualization requirements, it was necessary to consider how this visualization was going to be used. Unlike a product development effort that would seek to satisfy variable deployment environments, the final product developed for this research would be used to validate concepts in a controlled operating environment over a highly restricted time period.

Up to this point, the development environment(s) and computing platforms had not been chosen. Given the nature of form factor and differences in interaction style between computers (e.g. desktop, laptops) and portable devices (e.g. smartphones, tablets), it was necessary to commit to a platform. The dynamic nature of IT incident management is ideally addressed by a visualization residing on multiple device types. Supporting

multiple platforms would result in considerably more time in design, design review, development, testing and final evaluation. A single platform therefore had to be chosen. The Windows computer environment was chosen due to the abundance of computers available and development environments that were mature and freely available under academic licensing.

The time available for Independent Professionals to devote to the evaluation was also considered, and an hour was determined to be a reasonable commitment. Much more about the evaluation can be found in Stage V (Section 3.2.20). Only a fraction of the hour could be devoted to hands-on activity with the prototype, and the evaluation period was estimated to be 20 minutes long. This time budget subsequently affected the nature of the requirements that could be exercised, as well as shaping somewhat the types of evaluation tasks that could be anticipated.

Combining these practical constraints and the limitations inherent in only one person drafting the high-level designs, the diversity of high-level designs was severely limited. There was essentially one design proposed for each of the three leadership roles, with an alternative providing slight modifications. Some screens were rendered in multiple forms, but the overall structure remained constant. Inspired by the overlap in requirements priorities as seen in ranking requirements visuals (see Appendix H), the high-level designs had much in common across leadership roles.

The high-level designs were primarily pencil sketches with supplemental diagrams drawn in MS Visio. The supplemental diagrams provided screen flow as well as a break-down of evaluator activities over the 20-minute period. Examples of these diagrams are provided in Appendix J. Pencil sketches are not provided in this document due to their volume and limited visual clarity.

When comparing the requirements priorities and the screen functionality indicated by the screen names seen in Figure J.2 in Appendix J, the requirements associated with activities a user might perform during IT incident handling were manifested many

times as dedicated screens (e.g. screen "9 – Response Role Management" mapped to requirement "4D – Response Role Management"). Requirements that referenced less active needs (e.g. access to information types) were carefully accounted for, and in some cases significant real estate was provided on screens such as "3 – Personalized Response Summary" or "4 – Information Support Center."

A practical consideration was that the design requirements defined in Stage M (Section 3.2.12) span the entire lifecycle of incident management. It is unreasonable to consider an evaluation lasting 20 minutes as sufficient to cover handling an active IT incident, and then proceed to perform historical analysis on that incident as well as others. The evaluator would be overwhelmed by the pace and breadth of visualization concepts they would be expected to employ and evaluate. Therefore, the relevant portion of the IT incident management lifecycle had to be scoped, disregarding those requirements not relevant to that scope. It was decided to focus on those requirements that address time-sensitive decision-making taking place during IT incident handling. This means that requirements such as "7C – Control Change Evaluation" and "7A – Incident Management Improvement" would not be addressed in the upcoming design efforts.

3.2.15 Stage Q. Review High-Level Designs

3.2.15.1 Objectives and Methods

The objective of this research stage was to elicit broad design feedback by presenting hand-drawn sketches of proposed design alternatives. Another goal was to elicit practical considerations that could not be incorporated into the requirement development and prioritization stages. By providing high-level descriptions of design options, participants had an opportunity to consider potential solution approaches. The roughed-out designs were meant to encourage broad thinking, while not discouraging significant departures from the current design[52]. This preliminary review process was expected to eliminate poor design choices and properly position the design effort going forward.

The evaluation process involved presentation of each design alternative as well as implementation of a semi-structured interview process to elicit feedback. Unlike previous sessions with group members, the study protocol for this stage allowed for group review. In other words, in circumstances in which multiple group members worked for the same organization and knew of each other's participation due to internal coordination, those members were able to meet together to review the high-level designs. Assuming these members could brainstorm and communicate effectively in the presence of their colleagues, this allowed for feedback to trigger thoughts or provide exposure to ideas that a single member might not otherwise consider on their own.

This stage was designed to be performed in one pass. Given the expected post-processing overhead and limited value of additional iterations of the high-level design, it was best to assume that concepts or suggestions offered by a group member would not undergo any form of consensus building. The appraisal and potential acceptance of significant suggestions would rely on the researcher's understanding of the IT incident management problem space, as well as the constraints of the evaluation activities in Stage V (Section 3.2.20).

3.2.15.2 Outcomes

This review process was performed with all seven group members over twelve distinct sessions in aggregate. This included a group of three members who met together twice, two of whom were available to meet in a third session. Design review was done from the role perspective. Once again, professional biographical context of the group members would influence their assessment, so it was best to align the designs to the roles in which each was most comfortable. In the group review session, all three members had the Incident Coordinator perspective.

Member availability affected the consistency of the review. One member was able to meet only for about two hours, while the others met for over three hours.

The members offered a number of suggestions on screen content, beyond which they were asked to comment on the visual fidelity of the prototype that would best resonate with Independent Professionals. Their response overwhelmingly favored a higher-fidelity look and feel over a "sketchy" look. Microsoft's Expression Blend allows for prototyping to be done in high fidelity as well as a "sketchy" feel with low color content (i.e. functional controls that appear as if drawn by hand). It was explained to the members that a simpler look and feel had been shown to promote broader thinking by avoiding focus on relatively minor issues such as color and font selection. The group members did not think it was wise to commit to a sketchy look. They felt that most professionals would not appreciate the reasoning behind the selection, and that this lack of appreciation might interfere with their consideration of the content and the intent of the visualization.

A major architectural consideration suggested by the group was to allow the experience to be dynamic. Their rationale was that greater interest and engagement could be stimulated if the evaluator knew that their actions would affect the outcome of the IT incident. In essence, the suggestion was to make the evaluation a game. One suggestion was that a "Choose Your Own Adventure" storybook structure might be an effective way to construct this dynamic IT incident experience[53]. This suggestion was adopted and had a major impact on both software design and context development. An additional evaluation task (i.e. Task 6) was introduced, making what had been a casual glance at the "Closure Report" into an actual activity. This deliberate look at the report was meant to encourage evaluators to extract IT incident results and compare them to what might have been possible. This indirectly allowed evaluators to assess their performance.

3.2.16 Stage R. Analyze Design Review

3.2.16.1 Objectives and Methods

The objective of this stage was to extract design guidance from the feedback collected in the previous stage. The guidance consisted of recommendations for comparatively mi-

nor items such as color choice, and as major as reworking an entire screen or navigation. As design efforts to this point were limited to sketches and a broad sense of visualization capabilities, there was little previous investment to be lost in adopting the group's suggestions.

The recordings and notes were reviewed in order to identify and adopt more granular tactical requirements and visual design suggestions to identify and adopt going forward. The initial requirements were deliberately written to avoid implying any particular design approach. Having had the freedom to explore various ways to interpret the current requirements via high-level design proposals, and having received feedback on those brainstorming results, it was necessary at this point to identify more actionable requirements with less ambiguity in order to facilitate the upcoming development effort.

3.2.16.2 Outcomes

The seventeen distinct sessions, producing more than 22 hours of recordings, were reviewed and documented by taking high-fidelity notes of the conversations. Recommendations were translated into fine-grain requirements, which in turn were categorized as either prototype or evaluation requirements. Evaluation requirements were meant to influence development in order to ensure that the end result would be appropriate for the Industry Public Evaluation, as well as covering logistical and execution considerations. Inclusion of suggested requirements in these lists did not guarantee compliance. Documenting the suggestions in these lists ensured that they would not be lost and would be considered. The result of this stage was slightly more than 100 additional prototype requirements and roughly 25 evaluation requirements.

3.2.17 Stage S. Develop Visualization Prototype

In order to avoid duplication of content, the scope of this section is limited to discussing how the visualization development integrates with the overall methodology. Dis-

cussion of the visualization's design is found in Chapter 4 and the evaluation framework design in Chapter 5.

3.2.17.1 Objectives and Methods

The objective of this stage was to develop a visualization environment that was faithful to all stages, starting with Stage B (Section 3.2.3), thus resulting in a user-centered design. This depended on each previous step correctly interpreting and synthesizing inputs from group members, as well as the interpretation of relevant literature.

It is important to note that this research was being conducted to investigate a research hypothesis, and the prototype was to be a means to that end. The high-level design and any resulting prototype was the manifestation of requirements interpretation limited by the researcher's professional history, artistic skills, usability knowledge, skills with development tools and imagination. The same set of requirements could yield numerous design outcomes. Given these considerations, a tangible manifestation of the requirements was necessary, as it is difficult for most people to evaluate ideas in the abstract without constructive context. If final validation proved to be inconclusive or negative, the poor showing could in large part be the fault of a single design approach rather than a refutation of the overall research hypothesis.

For practical purposes, it was necessary to reduce the scope of the development effort. Developing three prototypes, or one prototype that could accommodate three roles, was a significant undertaking. Looking forward to Stage V (Section 3.2.20), it was necessary to consider the accessibility and size of the professional population with experiences as Business Leader, IT Leader and Incident Coordinator. By selecting one role, the number of screens could be reduced, with the number of requirements to be implemented limited as a result.

In order to manage the requirements and better ensure that their influence was proportional to what the group members indicated in Stage N (Section 3.2.12), practices

were adopted from Zultner's writings on Software Quality Deployment[50]. In his work, Zultner suggests the use of Quality Function Deployment (QFD) techniques in order to integrate the "Voice of the User" into the development process. QFD was originally developed and implemented in Japan for designing and manufacturing products. Zultner suggests that there are several disconnects between traditional QFD and software development, but that with minor interpretive adjustments QFD could be a valuable means to define and embed user needs throughout the development team and development cycle. The QFD process provides a structured method to convey the user's "voice" from the abstract levels of design to the concrete aspects of manufacturing a product. This structure is then introduced through a collection of hierarchical matrices that facilitate traceability. Given the limited research team size and operational expectations for this visualization, it was not found necessary to use (by some counts) all of the 30 to more than 150 possible matrices[50]. The key matrices used in this effort were Z1 and A1 – "House of Quality," implemented per descriptions and instructions of Zultner, as well as King[54] and Terninko[55].

Much of the voice of the user was expressed as requirements priorities. A second round of AHP-based prioritization could not be performed on these extracted requirements, as the context necessary for understanding these requirements would be challenging to develop and difficult for group members to appreciate (except, possibly, for the person motivating the requirement). Moreover, the requirements set was now much too large. Instead of returning to the group for more direct guidance, the approach taken was to consider the mapping of each second-round requirement to one or more requirements prioritized by the group members. In the event a second-round requirement mapped to more than one of the originally prioritized requirements, priority scores were averaged.

3.2.17.2 Outcomes

The selected leader role for visualization development was the IT Leader. This role provided a conceptual and organizational bridge between the Incident Coordinator and the Business Leader. There was also a sense that qualified Incident Coordinators were either much too busy or relatively rare, making it difficult to perform an evaluation with a sufficiently large sample size. Business Leaders were also considered to be less accessible, given their likely workloads and limited interest in exploring concept-level technology. This choice worked fairly well in terms of the alignment of professional histories of the Study Group members. Even if the members had no experience in the IT Leader role, they were nonetheless sufficiently familiar with it to make educated extrapolations based on their experiences working with colleagues in similar roles.

After combining the various evaluation constraints discussed to this point, a number of screens were removed from the development plan (e.g. "Incident Assessment & Response Center," "Incident Details Screens" (13.1 – 13.3), "Detailed Escalation Interface," "Incident Response Planning"), as well as several role-based customizations. Independent of priority ranking, nine of both high-level and second-level requirements defined in Stage M (Section 3.2.12), as well as roughly 25 second-round requirements resulting from the high-level design review in Stage Q (Section 3.2.15), were struck from development consideration.

The visualization was developed with Microsoft Expression Blend as a Sketchflow application. Sketchflow is a development environment used for rapid prototyping for visual designers, and offers portability that enables its targeted user community to review visual design and return feedback. A web browser-based visualization execution environment was chosen using Silverlight libraries and C# as the underlying programming language. A number of limitations of Sketchflow were overcome to build a medium-fidelity prototype that was state-aware and could accommodate the needed data persistence and context. This effort took a year to build a functionally complete prototype with minimal

data in order to proceed with Stage T (Section 3.2.18).

Screen consolidation took place during development because, as the designed user workflow became more concrete, having distinct screens for some functionality was neither necessary nor helpful to the user. Screens providing detailed treatment of content areas related to the Information Support Center were cancelled, since for evaluation purposes the capabilities within the Information Support Center screen itself were sufficient. Moreover, the additional information and alternate presentation approaches would likely overwhelm the evaluator. The "Report Repository" screen (not present in the screen flows in Appendix J) was developed to be a shell with no content and limited functionality. Reporting is a common tool in enterprise solutions, but proper functionality, as well as populated fictional content, had the likelihood of distracting evaluators who would be inclined to explore the depths of the prototype. Other than for the very last evaluation task, there was no need to review reports regarding current or past IT incidents.

3.2.18 Stage T. Review Visualization Prototype

3.2.18.1 Objectives and Methods

The group's objective at this stage was to review the assembly of evaluation-day elements that the Independent Professionals group would be exposed to and interact with. This was the last opportunity for group members to suggest corrections and contribute to the research.

A number of materials were prepared prior to conducting the Industry Public Evaluation. The materials were a pre-evaluation survey, an introductory presentation, the prototype and a post-evaluation survey. The survey instruments designed for the purposes of collecting data from the Independent Group participants had to be pre-tested. Group members were asked to experience the entire evaluation event and provide feedback. The feedback in most cases was elicited by semi-structured interviews prior to proceeding to the next element. The exception was the minimal feedback collected be-

tween the hands-on prototype activity and post-evaluation survey. These two elements were highly coupled. To best emulate the evaluation event, the transition between hands-on activity and responding to the second survey was meant to be nearly seamless. The second survey was the linchpin to validating this research effort, and was meant to collect initial impressions of the research. Given the importance of the survey instruments to this research, it was necessary that survey testing be carefully planned.

Survey Testing

By necessity, the survey testing protocol accommodated two key constraints, the first being that the only people able to effectively test the survey instruments were within the Study Group; thus the pre-testing sample size was quite small (i.e. seven or fewer). This was due in part to the unique ability of Study Group members to bridge between uninitiated professionals and the researcher who had worked with the group throughout the field study effort. Moreover, the Study Group members were the only professionals disqualified from the Industry Public Evaluation. Involving a new professional at this stage would increase the Study Group, but at the expense of shrinking the Independent Professionals population. The second key constraint was the necessity of testing in one round, as research schedule constraints and limited availability made more than one survey testing iteration impractical.

The questionnaires needed to be tested either by prospective respondents or reasonable surrogates in order to determine what the challenges might be (e.g. concepts, word choice, response design, biases, etc.). As the second questionnaire was tied to hands-on experience with the prototype, only those who had gone through the hands-on activity could effectively respond to the post-evaluation survey and provide reliable feedback.

The Study Group had seven people. Having looked at various sections within Presser[39] and Dillman's section on pretesting[38], it appeared that the cognitive interview tech-

nique was a very reasonable pre-testing method, given the available time and the limited size of the Study Group. According to Conrad and Blair[34], as well as DeMaio and Ashley[35], the cognitive interview was more a class of pre-testing technique than a well-defined methodology or protocol.

The two most prevalent cognitive interviewing techniques that appear in the literature previously mentioned are "think-aloud" and retrospective methods. According to Dillman[37], there could be undesirable consequences introduced by having the respondent read the printed survey question and then think aloud, as the self-administered paper survey was not inherently an oral instrument. Moreover, the group members had become familiar with semi-structured cognitive probes in other contexts, so retrospective methods might appear to be similar in style to past research discussions.

The degree of latency between respondents' question response and retrospective probes was another variable. Instead of performing retrospective probes after each question response, a unified set of retrospective probes was performed after the questionnaire had been completed. It was anticipated that the discussions between group members and the researcher might influence thought processes to some degree as members continued to fill out the survey. Like all previous sessions, these pre-testing activities took place in members' workplaces with limited controls, so the researcher had to be present to observe body language and other cues that might lead to retrospective probes. Some study members were extroverted thinkers, and it was anticipated that they might express themselves as they completed their survey form.

Dillman[37] suggests that the interviewer should formulate debriefing probes while the respondent is being observed. This approach is somewhat contrary to the IRB's need for review, so a set of primary probes was documented. However, like the semi-structured interview, latitude was needed to allow for additional inquiry on responses and unexpected reactions.

Beatty[33] identifies categories of utterances that cognitive interviewers made in the

interviews he reviewed. The surveys being pre-tested were interviewer-led, so quite a bit more dialogue occurred compared to a paper survey. The five categories are "Cognitive Probes," "Confirmatory Probes," "Expansive Probes," "Functional Remarks" and "Feedback." Among the probe types, both cognitive and expansive probes were conducted. Beatty suggests that expansive probes could cause interference, but as retrospective probes they are not expected to be a problem. Confirmatory probes were less necessary, given that responses were written down directly by the respondent.

DeMaio and Rothgeb[36] mention paraphrasing survey questions as an additional cognitive interviewing technique, with respondents asked to put the survey question into their own words. This intriguing technique was adopted because it had the potential to uncover both comprehension issues as well as alternatives in wording and terminology that might better resonate with IT professionals.

Pre-testing Objectives

The fundamental goal for pre-testing was to identify needs and ensure means of adjusting the questionnaire in order to facilitate accurate data collection. The following were the objectives of pre-testing both the pre- and post-evaluation surveys:

1. Identify comprehension issues with question content, question structure and reference period.
2. Identify awkward word choices.
3. Identify visual formatting challenges.
4. Identify survey questions that pose judgment and evaluation challenges, as well as likely causes.

5. Identify survey questions that pose retrieval-from-memory issues and possible means to compensate.

6. Identify survey questions that would likely be skipped and likely causes.

7. Identify issues with response terminology, response units and response structure.

Introductory Presentation Review

The group member was asked to sit through a presentation after finishing the pre-evaluation survey and related testing protocol. Since the previous survey review could take an hour, this next review stage was expected to occur in another session. The presentation was given in its entirety prior to any questions regarding its content being raised. A paper copy of the slides was given to the group member during this discussion to assist with recall. The questions asked were related to presentation clarity, and how content could influence interest and participation.

Prototype Review

In a user-centered approach to software design, this entire stage would, ideally, have been dedicated to a usability review. Moreover, the usability focus would have been on the interface elements associated with the IT Incident Visualization System. This was not feasible in the context of this research. In order to facilitate the Industry Public Evaluation, it was necessary that dedicated user interface elements be provided for the evaluation. Beyond reviewing the IT Incident Visualization System features and content, the group member performed the hands-on activity in a manner similar to the Independent Professionals. Thus the group member was able to provide feedback on the evaluation-centric interface components as well as their content. One critical content area was the set of evaluation tasks. The description, objectives and layout of the evaluation

tasks, as well as the available task completion choices, were critical. Independent of how well the IT Incident Visualization System functioned or addressed IT incident management needs, a misalignment between the task and the IT Incident Visualization System, or misunderstanding of the evaluation tasks, would have been detrimental. Frustration and confusion arising from these incidental elements (i.e. evaluation interface components and evaluation tasks) would not likely be compartmentalized from an evaluator's assessment of the IT Incident Visualization System.

3.2.18.2 Outcomes

Five members of the Study Group were available for this review stage. The structure and content of the review had to accommodate member schedules. This required that a "core" of the review be identified in order to ensure that the most critical evaluation elements were covered. The core was determined to be the pre-testing of the two questionnaires and the hands-on activity. The core review was conducted with the five available members. Those who had additional schedule flexibility reviewed the presentation as well as discussing the prototype.

A number of concerns regarding the pre-evaluation survey were raised during pre-testing. The most challenging issue involved the definition of an IT incident. Members agreed that it was an appropriate definition on the whole, but suggested alternative wording and punctuation to improve readability. Despite these suggestions, one anticipated challenge was the misalignment between this definition and those actually being used by organizations. As there is no generally accepted definition, the one being used was considered acceptable. It was anticipated that it would be difficult for respondents to align their own employers' definitions with this one. There are numerous ways to define and categorize IT incidents, and the categorization issue would cause problems with answering survey questions regarding costs and staffing related to past IT incidents. Other pre-testing feedback related to question wording, visual formatting and adding

additional questions. One challenge observed was related to scoping a respondent's employer or firm. The group's government members felt most highly aligned with their own departments (e.g. "Department of Revenue"), even though they were state employees. Another related scoping concern was a respondent's ability to provide IT incident statistical information for a scope much beyond their own workgroup. Some questions asked for firm-wide responses, but employees of large firms may have little awareness of events occurring at offices located in other cities and states, let alone other countries.

The post-evaluation survey raised relatively minor concerns from the group members, the most significant being related to questions 4, 10 and 11. Question 4 asked the respondent to compare their employer to "Zenodyne," a fictional company that manufactures composite materials. The original version of the question was somewhat ambiguous. And though none of the group members worked for a manufacturer, some responded to what they considered to be similarities between their own employers and Zenodyne, as the IT operational context considered in the evaluation exercise was fairly common.

The issue with question 10 was that the question asked the respondent to evaluate the value of having an objective calculation of the concept of urgency. In testing, it appeared that the question was not sufficiently anchored to the evaluation experience, making it unclear whether the visualization's treatment of urgency was being evaluated in their responses.

The issue with question 11 related to the response options. As opposed to a simple numerical continuum, phrases were denoting response range. This had the advantage of the respondent conveying a direct semantic value, as opposed to performing a numerical translation that raised interpretive uncertainty. The challenge, however, was that constructing a balanced language continuum was not straightforward. The original response options for positions two and three were much too close in degree to be semantically distinct. By contrast, the semantic distance between response options two and four, as well as between three and four, were too wide, so no adequate response option was available

within that gap.

The introductory presentation was adjusted as feedback was provided. This meant that the last member to evaluate the presentation did not see the same presentation as the first. Although this approach is statistically treacherous, the challenges raised needed to be accommodated immediately in order for the presentation to mature with repeated exposure. A poor presentation that lacked realism, clarity and accuracy was anticipated to have a significantly detrimental effect on the evaluation, whereas a good presentation was anticipated to have only a minor effect on evaluation results.

The prototype evaluation by group members was also uneven. The fictional context data necessary for the prototype to function properly, as well as to correspond to the evaluation tasks, was an active work in progress during this stage of the methodology. Unfortunately, the contextual data were difficult to prepare, while the research schedule would not allow a schedule slip of the "Prototype Review" stage. The scheduling objective was to begin the Industry Public Evaluation before the 2012 holiday season and winter weather, which could potentially interfere with recruiting and conducting the final stage. Members did their best to perform the evaluation tasks and complete the evaluation activity. Feedback was directed to the evaluation task descriptions as well as to their layout. Navigation controls within the prototype proved to be challenging to locate, and wayfinding was hampered in part by a limited understanding of the prototype's screen structure and content organization. A content-alignment issue existed with evaluation task two, causing confusion and delaying task execution. This delay may also be attributed to the difference in cognitive challenges between tasks one and two. The first task was designed to be a data-finding activity, and the second task was the first to require independent decision-making by the evaluator.

3.2.19 Stage U. Adjust Prototype

3.2.19.1 Objectives and Methods

The scope of this stage was broader than its name implies. The purpose of this stage was to adjust the materials designed for the Industry Public Evaluation that were reviewed in the previous stage by the Study Group. Adjustments were made with the intention of improving clarity, accuracy, usability and reliability, as well as the sense of practicality and realism of the pre-evaluation survey, introductory presentation, prototype and post-evaluation survey.

The pre- and post-evaluation surveys were adjusted according to the pre-testing in the previous stage. Forsyth et al. report that adjustments stemming from pre-testing may not yield improvements on every question[56], and they raise the possibility that it may not be possible to overcome the problems a question might have. They also recommend that iterative pre-testing be performed. Most "corrections" are essentially educated conjecture, thus effectively resetting the current understanding of each adjusted question's quality. As mentioned in the previous stage, iterative pre-testing was not feasible for this research project. With these realizations, as well as the limitations of the pre-testing protocol implementation, any adjustments to the questionnaires were simply a best effort. In addition to formulating changes to the questionnaires, the changes were processed through the IRB for approval prior to any administration of the updated instruments.

The introductory presentation was adjusted with regard to a given group member with respect to clarity, realism and accuracy. The prototype and closely related evaluation interfaces were adjusted per feedback from the group. Adjustments were sensitive to the frequency an issue was raised, their significance to the overall evaluation's success, and the feasibility of making an appropriate correction in the time available.

3.2.19.2 Outcomes

Sixteen adjustments were made to the pre-evaluation survey. One adjustment involved changing the order of paragraphs one and two in the instructions on the front cover. A new question three was added to identify IT expertise that may not have been accurately captured by the question related to tenure in a respondent's current job. For example, retirement and recent job changes could portray an experienced respondent as a newcomer to the field. Various changes were made to word choice in order to ensure the consistency of terms across questions. Question scoping was a common adjustment. One of the more significant scoping changes was related to the breadth of the work environment being considered. The term "firm," originally used in questions 14, 16, and 17, was replaced with "workplace." Employees of larger employers may have found the original scope too broad. The original response format for questions 16, 17 and 18 was in the form of a graduated horizontal scale designed to accommodate a single response value. The scale, which needed to accommodate a broad range of possible responses and the visual weight of all the various lines on the scale, was found to be confusing. The scales were replaced with fill-in boxes to accommodate a less constrained response.

Seven adjustments were made to the post-evaluation survey. The adjusted survey questions were nos. 4, 5, 7, 8, 10 and 11. For question 5, the word "consequence" replaced "significance." Question 7 underwent a minor word replacement to improve clarity, and questions 10 and 11 were adjusted to accommodate the observations discussed in the previous stage. Overall, the adjustments to this instrument were fairly minor. The final survey instruments can be found in Appendix A.

The prototype underwent mostly cosmetic changes to improve a user's ability to locate navigation controls. Context data adjustments were made to improve the tie-in with evaluation tasks. The layout of the evaluation task description was made more consistent, and better labeling was used for the components of the task description in order to improve the user's ability to discern the intention of the task description elements

(e.g. "Orientation – A description of what has happened between the tasks, what is to be done and why it is to be done"). Significant changes to the prototype's navigation and wayfinding were not feasible in the time allotted.

3.2.20 Stage V. Industry Public Evaluation

In order to avoid significant duplication, much of the detail related to the Industry Public Evaluation is found in Chapter 5.

3.2.20.1 Objectives and Methods

The purpose of this stage was to have Independent Professionals assess the merits of the business impact visualization system designed in cooperation with the Study Group. The evaluation was intended to recruit around 20 – 30 IT professionals to evaluate the resulting visualization prototype in a prepared scenario setting. The evaluation was a structured event planned to take not much more than an hour.

Two evaluation settings were organized. One setting was a public evaluation in which the call for participation was made to IT professionals in the Des Moines metropolitan area. Facilities were arranged in various locations in the metro area based on their convenience to various concentrations of IT employment in the area. Flyers were sent by email to various group lists to which professionals subscribe. The events were restricted in participant numbers due primarily to the amount of computer equipment needed and the cargo capacity of the vehicles likely to be used. An Internet service (i.e. Eventbrite.com) was used to provide online registration. Although anonymity was preserved in data collection, it was necessary for participants to register in order to track attendance, as well as to ensure that the event would not be oversubscribed, thereby disappointing those who had made time to participate.

The second evaluation setting was the private evaluation. Organizations were asked to host evaluation sessions at their facilities and invite employees to attend. Scheduling,

recruitment and attendance management were performed by the host organization. The size and structure of these private evaluations were to be consistent with the public evaluation. The most significant distinction from the public evaluation was that participants in the private evaluation came from the same general organization.

The evaluation event was structured to provide an uninitiated IT professional an overview of the research effort, explain the scope of their involvement, provide brief training on the software, and collect data from them. This fast-paced activity was designed to capture first reactions to visualizing IT incident management concepts and activities that, up to this point, were managed with isolated technologies or facilitated in limited visualization settings. The pace of this evaluation was in large part necessitated by the practical restrictions IT professionals have on their schedules for extracurricular activities. Some employment settings would likely require a professional either to deduct time spent participating in the evaluation from their timecards or bill against overhead accounts.

3.2.20.2 Outcomes

Outcomes related to Stage V are discussed in Chapter 6.

3.3 Discussion

Designing and executing this methodology over the span of the research effort resulted in significant observations and lessons learned, some of which will be shared in this section.

Ideally, the documented methodology would have been designed prior to starting. However, a number of adjustments to this plan were made, as practical experience showed some plans to be inadequate or naïve. Before starting this research, the methodology was sketched out in the following sequence (see Figure 3.1 – Note: current stage labeling

used below to provide consistency):

Stage A. Define Problem and User Group

Stage B. Understanding the Need

Stage G. Need/Task Selection

Stage H. Understanding Selected Task

Stage P. Develop High-level Designs

Stage Q. Review High-level Designs

Stage S. Develop Visualization Prototype

Stage T. Review Visualization Prototype

Stage U. Adjust Prototype

Stage V. Industry Public Evaluation

All but three additional stages in the final methodology were strictly researcher activities. One could argue that many of the additional researcher activities could be consolidated; however, such consolidation would mask their significance. Iterating back to the Study Group was time-consuming but, more importantly, would have been ineffective if improperly executed.

As relates to the initial exploration into business impact visualization, the range of complex visualization needs could not have been anticipated. With such a diverse set of needs, it was necessary for the Study Group to weigh in. The iterative nature of this research required the Study Group to have a steady population. Group members' interest in the chosen visualization was necessary for them to remain engaged.

To avoid future failure, it was necessary that "Stage E. Prioritizing the Needs" be introduced. The requirements prioritization process was absolutely critical. It was naïve to think that, absent input from the Study Group, requirements would be unambiguous or relatively simple to establish and sort prior to executing Stage P. IT incident management is a complex problem. The interpretation of the task exploration in Stage H

was challenging. The process of distilling an understanding of IT incident management into visualization requirements was, in part, subjective. Beyond confirming the validity and completeness of requirements, the Study Group was needed to prioritize them.

One practical challenge of this research related to the privacy and confidentiality of the participants in both the Study Group and Independent Professionals group, with the greatest concern being the Study Group. The initial probes into problem areas, as well as performance of those tasks, had the potential to expose weaknesses, deficiencies, organizational dynamics and other sensitive information. Only one non-disclosure agreement (NDA) was signed. The other participants considered NDAs, but instead simply chose to be discreet in how they responded to questions involving employer operations. Trust in the researcher's own discretion was necessary to complete this research. Due to this trust, the recordings and notes from these discussions were closely held, and the research team was therefore quite small. In order to maintain the confidentiality entrusted to the researcher, the researcher performed all audio recording review and related documentation. Formal transcription was not practical, given time and resource constraints. Detailed notes were taken that include long passages of verbatim transcription, but full dialog transcripts were not considered practical.

The methodology would have been best executed if the Study Group members had the opportunity to evaluate the high-level designs and final prototype with context-relevant information. Given the complexity of establishing a coherent fictional context in which to populate the drawn or developed screens, limited placeholder information was the best avenue available at the time Stages Q and T were executed. During Stage T, some group members went through the hands-on activity with inadequate visualization content for executing the evaluation tasks, which limited the range of their feedback.

The practical and ethical requirements to isolate each Study Group member for much of the field study was challenging from a knowledge-attainment perspective. Although many of the same questions were asked, the responses were at times wide-ranging. This

provided insight into the breadth of the problem space, but without confirmation from other members it was unclear how frequent or general any particular observation might be. This necessitated the processing of collected inputs and returning for confirmation at a later stage. When meeting with group members to initiate a subsequent stage, it was necessary to review the results from processing the previous Study Group activity stage. Many of the subsequent Study Group stages followed significant decision-making or design efforts. Waiting for confirmation was disconcerting, but to return for further discussion without making concrete progress toward the end goal eventually would have met resistance by group members, as well as impeding project progress.

Execution of this methodology by a single researcher is not advised. This methodology was labor-intensive. The financial and personal status of the researcher must be secure. There was significant risk in embarking on a solo research effort that took years to reach a tangible result. Another thing to consider is change in employment status for Study Group members: four changed jobs (three members of which remained fairly accessible), and another was on the verge of retirement by the end of the study.

CHAPTER 4. IT INCIDENT VISUALIZATION SYSTEM

This chapter examines the reasoning and purpose of the visualization design resulting from the iterative field study discussed in Chapter 3, and some of the specifics of that design are discussed.

Also, an explanation of the relationship between the Iterative Field Study Methodology and visualization design is provided, followed by a section that explores the IT Incident Visualization System. The chapter closes with some brief observations in the "Discussion" section.

4.1 Introduction

This business impact visualization research was focused on addressing the hypothesis that is stated in Section 1.4. In Chapter 3 and associated appendices, a number of ingredients that could yield numerous different (and ideally effective) IT incident management visualization solutions are discussed. This chapter discusses the visualization approach developed to instantiate concepts produced by this research.

4.2 Iterative Field Study Methodology

It is not possible to separate the evolution of this visualization research from the methodology that informs it. Beyond the initial rough shaping of the research orientation around improving business leader awareness and comprehension of security and compliance decisions, the intermediate results of the methodology provided the focus,

explored the problem, specified the function, and inspired the visual dimensions of the resulting visualization. Although this visualization was crafted by a time-constrained researcher with limited field research experience, as well as imperfect understanding of usability, graphical and development techniques, the effectiveness of the visualization rests to a significant degree on the power and pitfalls of this field study methodology.

4.3 Visualization

In her thesis on biological network visualization, McGarthwaite identifies five visualization fields, which are "Artistic Visualization," "Knowledge Visualization," "Data Visualization," "Scientific Visualization" and "Information Visualization"[57]. Among these fields, Card et al. would classify the visualization being undertaken by this research as Information Visualization, as the subject and related data sets are abstract[58]. This distinction is important because designing a usable IT Incident Visualization System is hampered by the challenges users might have interpreting second order abstractions (i.e., the first level of abstraction is the subject matter, the second is the visualization construct used to present the subject matter-related data). Since the improvement of business leaders' awareness and comprehension of IT incident decisions is the objective of the visualization design, a careful balance is needed to ensure that the potential of visualization is leveraged while usability needs for task performance are met. This consideration is consistent with Card et al., who state, "The purpose of visualization is insight, not pictures" ([58],pg. 6).

This section discusses a number of important design elements and principles that are the foundation for the reasoning and purpose of the visualization designed. Figure 4.1 illustrates how visualization design objectives relate to IT incident management objectives, and provides an overview of the discussion that follows.

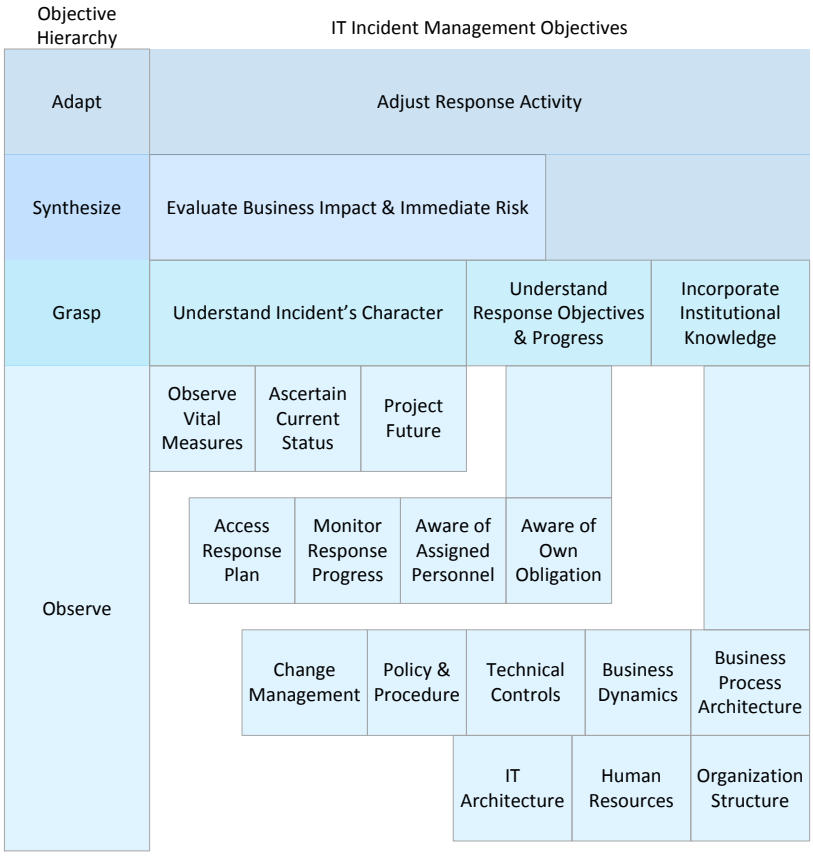


Figure 4.1: Visualization Design Objectives

4.3.1 IT Incident

There are numerous definitions of an IT incident. A widely recognized set of international IT services management practices known as the Information Technology Infrastructure Library (ITIL) has promoted a number of definitions. According to Brewster et al., the current version (v3) states, "An incident is an unplanned interruption to an IT service or reduction in the quality of an IT service. Failure of a configuration item that has not yet impacted service is also an incident" ([59],ch.26). Another widely recognized set of practices known as Control Objectives for Information and related Technology (COBIT) aligns its definition to ITIL. In Appendix VII of COBIT 4.1, the definition of

an IT incident is given as "any event that is not part of the ordinary operation of a service and that causes, or may cause, an interruption to, or a reduction in, the quality of that service (aligned to ITIL)" ([60],pg. 191). These definitions cover a very large range of events that may have operational, security and/or compliance impacts. Not only is the range of event categories large, the impacts themselves range from an employee needing a virus removed from their personal computer to service disruptions impacting thousands of employees or customers. ITIL allows an organization to define the latter incident as "major."

For this research, an IT incident is defined as "an event that [negatively] affects the integrity, confidentiality and/or availability of information and information systems. These events have *sufficient impact or risk* that merits the *collaboration* of leadership personnel *beyond* the workgroup."

Unlike the others, this definition specifies the qualities of service that, interpreted broadly, cover security, compliance and operational events. The distinction this definition makes is in scoping the incident in terms of the personnel dimension. The challenges regarding leadership engagement in IT incident handling explored in this research do not typically arise in situations in which the necessary response workforce is self-contained within a single team. Another criterion for IT incidents of interest is when an incident's impact or imminent risk is sufficient to require involvement of the leadership of the service provider and service consumer(s). The duration of the IT incident is also another limitation on the effectiveness of a near real-time visualization solution for leaders. An incident that is identified and resolved quickly is not likely to involve leaders during handling of the incident, as technical staff will resolve the issue on their own. Leadership involvement will occur only afterward in the form of incident review, or possibly when reviewing collections of incidents for the purpose of process improvement.

4.3.2 The Fit

Typically, IT incident management is viewed as a continuous process-improvement cycle. For the purposes of this discussion, an IT incident management cycle is depicted in Figure 4.2. While leaders are a part of every phase of the IT incident management cycle, the most noteworthy decisions are related to escalating a problem to incident status and facilitating the ensuing response to the point of closure. And while leaders will occasionally review significant incidents individually, decision-making commonly resumes when reviewing a collection of incidents over a time frame. As part of the continuous process-improvement model, lessons learned will translate to changes in administrative, process and technical controls in order to prevent similar incidents from recurring. Due to the impacts these changes have on the business, evaluation and approval of changes in control practices require leadership decision-making.

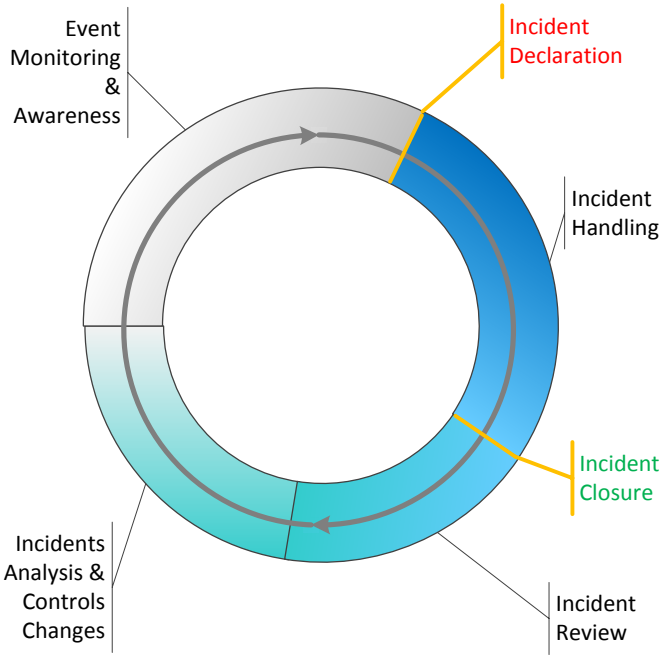


Figure 4.2: IT Incident Management Cycle

In Appendix E, there are a number of requirements (listed in Figure 4.2) that address

the “Incident Handling” and “Incidents Analysis & Controls Changes” phases of IT incident management. Requirements prioritization directed this visualization design toward the time-sensitive aspects of supporting leaders in an active IT incident situation. An important transition from “Event Monitoring and Awareness” to Incident Handling is the “Incident Declaration.” This visualization has an inherent process-support discontinuity in that the decisions surrounding Incident Declaration are not supported. Moreover, the field study did not investigate or formulate requirements for this key transition. As the visualization design is discussed, consider that an IT incident declaration has been made, and that the design assumes an IT incident has been fully initialized in the system by means outside of the design.

4.3.3 The Gap

Software vendors have developed products in support of incident management and, more specifically, IT incident management. Much of the value these products provide is in guiding technical responders through the workflow of incident response. Major market leaders (e.g. BMC, HP, Service-Now [61]) target their IT incident management systems to be compliant to ITIL practices; accordingly, the IT incidents they address are those defined by ITIL. These systems are built to support the wide array of small-scope incidents that occur in a given year for a particular organization. The “forest” is being addressed, but the high-value “trees” – the IT incidents, as defined in this research – are underserved. A consequence of process improvement is that high-value or unusual IT incidents have a greater tendency to be technically complex, and therefore will involve an assortment of people. The field study found that response teams resort to manual and segregated technologies to coordinate and communicate.

4.3.4 The System

Communications is an essential part of incident management. It is through communications that problems are identified, solutions developed and approved, resources applied, resolution and remediation achieved, and recovery known. Enterprise-oriented IT incident management involves many people with a wide range of responsibilities, professional backgrounds and interests. The diversity of the personnel involved reflects the breadth of an incident's scope. Let the people involved be called the "community of the interested," which consists of the five core and two secondary roles discussed in Section 3.2.9. The assignment of actual people to roles is a function of the organization's culture, organizational structure, available skills and, most importantly, the incident's specific set of attributes. It is safe to say that incidents happen. Incidents vary widely in their frequency and specifics, so role assignment is dynamic from one incident to another, as well as when changes occur within a single incident. Unlike professional communities such as paramedics and firefighters, organizations find assigning personnel strictly to IT incident management to be prohibitively costly, especially when incidents are infrequent, unpredictable and variable in nature. As technology commitments increase, organizations experience higher IT incident frequency and business risk. As a result, organizations with very large IT investments have personnel trained and assigned to redirect their attention to IT incidents. And though many of their leaders are not dedicated to incident management, they nonetheless participate in potentially dozens of incidents a year because of their relevant skills, knowledge, authority and operational responsibilities. By contrast, other participants may experience only one incident over their entire careers. This results in a community of interest being assembled quickly, and possibly with limited prior experience interacting with each other. As such, the common context necessary for effective communication, and even the lines of communication themselves, are hastily established with varying degrees of success.

This visualization system was intended to provide the conceptual and perceptual

bridge between members of the community of interest. The primary audience for this visualization's initial design was leaders within IT services and of business operations. The goal was to allow them to establish the necessary context and understanding in order to make incident-relevant decisions. Beyond improving awareness and understanding, a visualization objective was to facilitate improvements in decision timeliness, incident response coordination, response and decision error reduction, and management of the incident response process. The secondary audience was the response team members. Response team members should find in the visualization a means of sharing their knowledge and understanding of incidents, as well as achieving awareness of the specific information leaders are accessing as they evaluate the incident, its related response and, more generally, incident management as a business process.

4.3.5 Concept Model

According to Norman, a user develops an understanding of how a device (e.g. door, automobile, visualization program) functions from observation and experience[51]. Through this understanding, the user achieves a level of comfort by being able to anticipate how the device operates. In order to explain how the visualization functioned, this subsection describes the concept model developed during high-level design and implementation to govern use of the system.

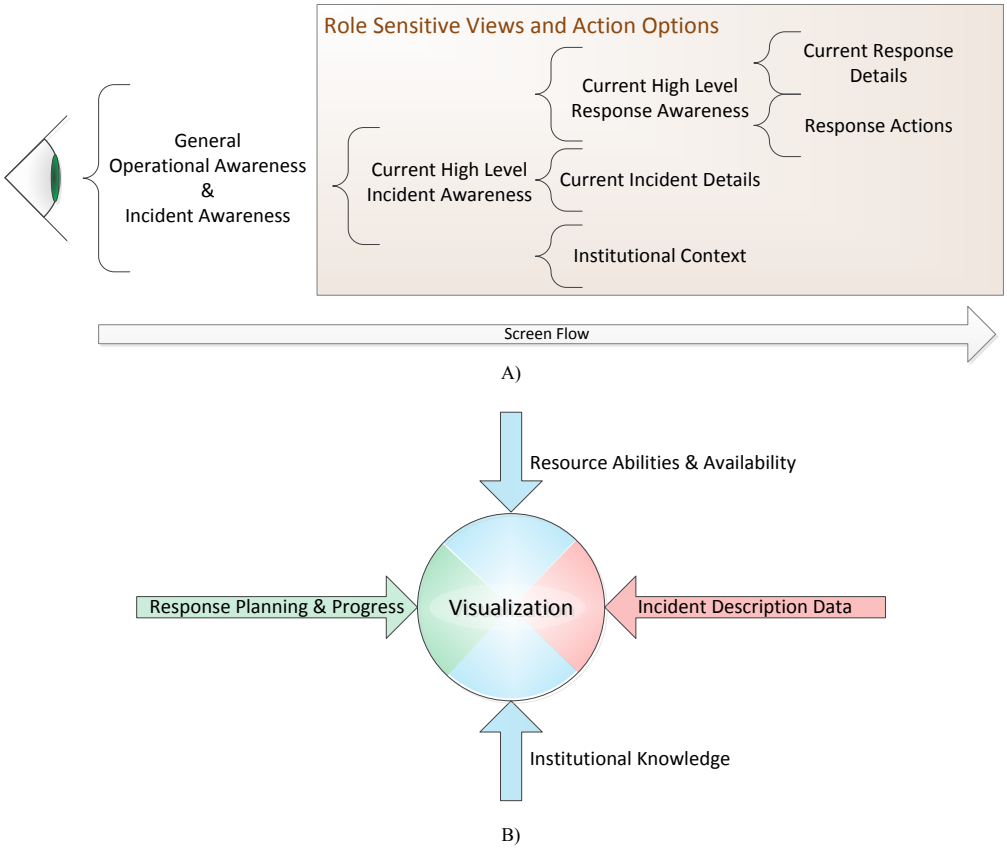


Figure 4.3: Concept Diagrams: A) Content Access, B) Primary Data Types

A fundamental principle in the visualization's design is that awareness and context are needed for effective decision-making[62][63][64]. Awareness is facilitated prior to enabling any action and, if space permits, active situation status is provided in juxtaposition to action enablement.

The visualization is composed of multiple screens that address leaders' needs as specified in the requirements (see Appendix E). Instead of attempting to consolidate all necessary information into a few high-dimension visual abstractions, much of the information was presented in forms similar to those seen in common practice. Action-based requirements, such as response role management, were facilitated in dedicated screens. These two design choices led the design to incorporate a collection of screens organized

into three content groups: "Incident Awareness," "Response Awareness & Management" and "Information Support."

After getting past the initial authentication screen and "legal notice" (evaluators saw a disclaimer regarding populated content), the first screen was the "Grand Summary." This screen was meant to be an interactive overview of the operational status of business processes as well as an overview of active IT incidents. Figure 4.3.A illustrates the content and functionality flow. Having a broad sense of the operating conditions of the organization, the user could explore the incident details. The "root" screen of the incident specifics was an overview screen (i.e. "Incident Summary") focusing on IT incident characteristics. When the user selected the incident of interest, the visualization environment was intended to adapt to the user's assigned response role.

Support only for the IT Leader role was implemented in this prototyping effort. IT Leaders saw an incident summary screen tailored to their role. Until the user returned to the Grand Summary, all subsequent screens' contents were dedicated to the chosen IT incident and oriented to the user's assigned role. Having the opportunity to see the high-level view of an incident's characteristics, the user was able either to investigate greater incident status detail, access the Response Awareness & Management content group, or seek out general information from Information Support. After analyzing the decisions made by leaders, it was observed that many decisions were in part dependent upon context that was fairly universal across IT incidents (e.g. organization structure, human resources, regulatory concerns, policy & procedure, IT architecture). The Information Support content group provided ready access to institutional context. The Response Awareness & Management content group, accessible from the Incident Awareness and Information Support content groups, started with a summary overview of response status. One challenge for a leader with duties beyond handling the IT incident was keeping track of tasks that might await action from them or anyone else sharing their role. The "Response Summary" screen provided a view of actions assigned to the user. Armed

with a broad awareness of response efforts and responsibilities, the user could choose greater response details or take actions to facilitate the response.

4.3.6 Data Sets and Integration

This visualization design was based on integrating and making core data sets available in order to improve user understanding. The objective was to give leaders access to a consistent and effective automated representation of the IT incident that replaced or minimized the need for the Incident Coordinator to manually assemble a snapshot of IT incident conditions, as well as to reduce the number of intermediate status updates requested by individual leaders. Figure 4.3.B is a portrayal of the types of data sets feeding into the visualization system.

The fundamental data sets were "Incident Description Data," "Response Planning and Progress" and "Institutional Knowledge." Within Institutional Knowledge, "Resource Skills and Availability" was a critical subset. The data sets helped answer common questions, e.g. What is the current nature of the IT incident? What is being done to address the incident? Is what is being done reasonable given the current and projected nature of the incident? What do I need to be doing to assist with the response? Do we have the right people for the job? Who has skill "X" and is available to assist? How much longer do we think the IT incident will be active? When do we expect to have an intermediate restoration of services?

The visualization's concept of operations was that the visualization not be an authoritative source or long-term repository of information maintained elsewhere. If, for example, response planning and progress data were unique to the operations of the visualization, then the system facilitating the visualization would likely house that information.

4.3.7 Design and Principles

Visualization design took place in two stages: first the high-level design, and then prototype development. Much of the visual design laid out in the high-level design was implemented in the prototype. As discussed in Chapter 3, additional scoping took place during development, which resulted in reducing the number of screens relative to the high-level design. Many of the navigation and interactive aspects of the visualization were designed during the prototype development stage. As the visualization design and related principles are discussed, distinctions between the high-level design stage and the prototype development stage will not be maintained unless they become necessary.

4.3.7.1 Operational Platform

As mentioned in the requirements (Appendix E), thorough implementation of an IT Incident Visualization System would best be done across multiple computing platform types. But as multiple platform development and evaluation was not feasible, a single platform was chosen, namely, the Windows 7 personal computer running a web browser with Silverlight libraries. This puts the user in a stationary operational setting similar to a user's workspace (e.g. cubicle, office, operations center workstation). With the user in one location, it was decided to maximize screen real estate. The screen was assumed to be capable of 1680 x 1050 resolution, which is fairly common. No other application was intended to share this screen space. While this was necessary for the evaluation, in practice a second monitor would likely be necessary for this design to accommodate a user's other computing needs.

4.3.7.2 General in Design

Although the ultimate validation of this research was to be performed in a highly controlled setting that would provide an evaluator a limited opportunity to utilize the visualization's full functionality, this did not overly impede efforts to seek general so-

lutions. Some requirements were discarded as the development scope narrowed, but requirements that were in scope were explored beyond what was strictly necessary for the evaluation. The approach was driven in part by the iterative nature of evaluation task development, as well as the fact that the final IT incident was not specified until after the high-level design was completed. Another reason for this approach was that the evaluation did not seek to determine if there was strict improvement with regard to a single IT incident type. The strict adherence of design and implementation to the evaluation's limitations could have jeopardized the evaluator's ability to project the research's value and relevance beyond the planned experience. The evaluation incident was simply a means for evaluators to appreciate how visualization might improve IT incident management for them personally as well as for their employers.

When visual concept generalization was too difficult to implement, a manual snapshot approach was taken. Graphic library development was well outside the scope of this effort, so in numerous cases static presentations were developed. However, much in the manner of a cartoon, the illusion of dynamic presentation was achieved by replacing a static presentation with a new one presenting updated narrative content. These implemented visualization elements became tightly bound to the evaluation narrative.

4.3.7.3 Monitor and Investigate

While designing informational screens, the usage pattern of "monitor and investigate" guided many choices. In monitor and investigate, the person scans a screen to achieve an awareness of the topic being presented. A user may or may not have an initial goal while scanning or browsing across the various information elements presented. In the event that something catches the interest of the user, the user can explore further by interacting with the screen. This is similar to the interaction pattern Tidwell characterizes as "information browsing" [65], and is consistent with Shneiderman's maxim of "Overview first, zoom and filter, then details-on-demand"[66][67].

The “drilldown” capability was designed at a macro level in the form of supporting detail screens accessible from the summary level. Within screens, information details were provided in table-row expansion, populating data fields upon graphic object selection, and in explanatory elements that appeared while passing the cursor over an information item.

In order to support initial monitoring, information dimensions were carefully selected. Care was taken to avoid having the primary information dimensions of a topic accessible only by interacting with the screen. There were cases when the visual dimensions of what was presented exceeded available space, a less than ideal situation. When feasible, zoom controls were implemented in order to allow the user to view the broad pattern and seek out details of interest. Ultimately, scrolling could not be avoided, but having to perform an interaction pattern of “scroll-and-interact” in order to locate a primary information attribute was avoided.

4.3.7.4 Cognitive Fit

There is a common notion that a task affects the user’s information needs, but more subtly, the task may influence the appropriateness of the presentation style. This concept was considered throughout the design. Typically, this consideration (i.e. cognitive fit[68][69]) resulted in manifesting data in both textual and graphical forms. In many situations the simple juxtaposition of textual elements in proximity to their graphical counterparts was not practical. When possible, alternative views were presented incorporating the same information in both textual and graphical formats. This dual representation did not override the design consideration of “Monitor and Investigate.” Except for a few cases, the two representations could not be utilized concurrently. This was a reasonable design choice, considering that a user performing a task sensitive to cognitive fit was not likely to utilize both representations simultaneously, as the alternative presentation is likely not needed within the field of view.

4.3.7.5 Familiar vs. Novel Abstraction

Information graphics for the visualization were selected for the most part to be familiar. IT incident management is an abstract-concept problem domain. This assertion is based on an IT incident's dimensions of extent, cost, security, and compliance, as well as future projected costs. Additionally, there is likely to be error in calculating actual costs. There is uncertainty with any projection, including uncertainty of future costs. The concept of "extent" includes the effects upon business processes, organizational units, personnel, data sets (e.g. accounts receivable, customer financial information) and physical technical components. What does a "security concern" look like? A security concern does not lend itself to obvious representation, so attributes of the security concern are selected for visual representation. But which attributes should be selected? Will the attributes of interest remain constant across all security concerns? Mapping all these IT incident characteristics into a single novel visual metaphor would take much effort by the user to unravel and achieve sensemaking of the IT incident. "Sensemaking is a motivated, continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively" ([70],pg. 71). This was a pragmatic consideration, given the nature of the impending validation stage. Furthermore, in practice it would take more research to develop appropriate visual metaphors, as well as to provide user training before new presentation techniques would be usable.

4.3.7.6 Broad IT Incident Support

Functionality was not tailored to an incident type (e.g. server outages, data breaches, slow networks). The design did not seek to perfect incident handling for a specific IT incident or incident class, but rather proposed that a response plan appropriate to the IT incident be configured during response operations. This plan provided the cornerstone information structure on which all Response Awareness & Management was based. The response plan could be expressed to address many IT incident classes, and the granularity

of the plan was not constrained by design. Incident Awareness was designed to be consistent in presentation and functionality across incident types. Functionality of the Information Support content group was by definition general to all incidents.

4.3.7.7 Business Process Relevance

Associating an IT incident's impact on application architecture and related technical components might have offered a satisfying level of relevance for a technologist. However, technology is simply one resource contributing to the execution of business processes. To those evaluating business impact, it is necessary to characterize an IT incident in the context of the business operations affected. Virtualization, increased computational capabilities, high-bandwidth communications and other technical advances have been increasing the degree of business dependence on identifiable physical components. In a given ecosystem, an IT incident involving a single server may affect multiple business processes directly; and, as with dependencies between processes, an unresolved IT incident's impact can cascade into previously unaffected operations.

Business processes, regulatory compliance and security risk are all highly correlated. Many business processes manipulate information in their inputs and outputs, and in many cases the data operation adds value to the organization. Assignment of business processes to technology resources imbues those resources with regulatory and security risks associated with the business processes. An email server and e-commerce server may be of the same make and model running the same operating system, but business impact with regard to compliance and security would not be the same between them if both were affected by an IT incident. A technology component supporting multiple business processes will have a security and compliance profile that joins the business process profiles it supports.

In visualization design, the business process overlaying the technical architecture is presented when the context is relevant (e.g. an IT incident's extent).

4.3.7.8 Content Group: IT Incident Awareness

IT incident awareness involves knowledge of the existence and an understanding of the nature of an IT incident. There are several social factors that affect awareness. An IT incident may occur that management deems too sensitive for common knowledge. Or, an IT incident may occur that affects a part of the organization in which a leader has no interest or that is unlikely to affect the leader in any appreciable manner. There are IT incidents to which leaders are either obligated to respond, or at least be aware of, in order to anticipate possible impacts on areas of the business for which they are responsible. These high-level factors govern interest in and access to IT incident awareness.

IT incidents are significant unplanned events that negatively affect the business through reduction of the availability, integrity and/or confidentiality of information and information systems. IT incidents are commonly measured and characterized by their symptoms or impacts before their root cause is established. In some cases, the root cause is not in itself sufficient to describe the incident (e.g. power outage or malware infiltration), yet the symptoms are useful for continued monitoring.

IT incident characterization is somewhat role-dependent. Although the same IT incident is being characterized, the responder's role strongly influences the lens through which he or she interprets the nature of the IT incident. A technical responder tends to assess the incident as an event in the domain in which they have expertise. For example, while a "zero-day" malware outbreak with a worm component to facilitate replication may be a nuisance to network administrators, to the PC support person it is a vulnerability mitigation challenge, a virus signature distribution problem and, possibly, a manual cleansing process. The network security staff sees this malware as a possible data breach leaking information to Internet servers in other countries. Some interested leaders may be concerned about malware incident response costs and the ongoing threat to productivity, while others worry about regulatory compliance as the infection spreads to computers that are used, for example, to regularly process customer financial records or

personal health information. The security forensics people want to know which computer was "patient zero" and who operates that computer, as well as what information was targeted, if any.

These are all valid points of view, albeit limited in perspective. In the long run, however, the visualization needs to support awareness of all supported response roles. There are two aspects to consider in supporting awareness: first, the information elements needed for awareness and, second, the form in which these information elements are presented. This visualization was designed with different views to IT incident-awareness attributes sensitive to response roles. During implementation, presentation ideas for the Business Leader and IT Leader merged to some degree.

Intrinsic IT Incident Attributes

Characterization of an IT incident is contingent upon the intrinsic attributes of the incident that can be measured, computed, forecasted or observed. The attributes identified over the course of this research were time, direct incident cost, direct incident cost risk, extent and urgency. Of these five attributes, incident cost and extent primarily involved measuring the incident's past. Time was a measure that spans the incident's beginning to its projected ending. Direct-cost risk and urgency were measures of the incident's future. Urgency was actually a composite measure, incorporating direct-cost risk as well. The objective of having forecasted measures was to inform decision-making. Although the damage and cost incurred to date influence decision context, decision-making is primarily forward-looking to the point at which someone determines there is nothing left to anticipate from the incident and decides to close it.

Time

Time is a fundamental measure of IT incident response that could easily be overlooked or inadequately addressed. A visualization user's interest in time is in the context of occurrence, time of cessation, duration, and time remaining before the expected initiation or cessation of an event, action or task. Time is an essential attribute in logistics, as well as providing context for many other decisions or judgments. In terms of duration and delay, time can involve key thresholds for escalation and priority.

Direct Incident Costs

Direct incident costs are the actual costs incurred as a result of the incident. Calculating direct incident costs involves computing a value that results from accounting for response resources commitment, hardware replacement costs, lost productivity, measurable contractual penalties and lost revenue. Labor-related costs can become difficult to ascertain in practice and are sensitive to the time-accounting practices an organization may follow. Costs associated with salaried workers who do not assign their time to particular projects are difficult to measure accurately. In such cases, the "wages" applied to each resource's time are somewhat arbitrary. Punitive costs and regulatory fines are also direct costs, but may take years after the incident closes to determine with any finality. Knowing the direct costs allows users to appreciate the IT incident's true impact.

Direct Incident Cost Risk

Direct-incident cost risk is a cost-rate projection of anticipated direct-incident costs. The objective of this measure is to allow the user to assess what a probable cost rate would be if the incident were to continue into the future. By having an appreciation of future costs, the user has an important measure of immediate business risk associated with the incident. No formal algorithm was developed for this research, but a vetted

algorithm would be needed for this measure to be useful.

Extent

The extent of an incident involves reporting the incident's scope-of-impact across the business. Unlike other attributes that are largely summative values, extent is a detailed descriptive attribute. It was treated as a highly graphical attribute because the inter-relationships presented would be very difficult to express otherwise. This is a technical attribute on which technical responders would likely focus most of their attention. Extent attempts to describe the literal nature of the IT incident by expressing whom and what the incident has affected. In many cases, the cause and any ongoing activity are occurring in an environment no person can observe firsthand, but only indirectly by their impact on the environment. A medical analogy might be the observation of a person's symptoms from being infected with influenza without being able to watch the virus and the person's immune response in action under a microscope. Given the complexity of the inner workings of an enterprise IT environment, it is highly challenging to express extent in a manner sufficiently comprehensive to satisfy all users' needs. Therefore, the presentation and dimensions of extent (e.g. impact in relation to network infrastructure, storage, network security controls) are role-sensitive. Extent presentation for the Incident Coordinator is oriented toward diagnosis and tracking, but toward business impact and immediate risk for the Business Leader and IT Leader. In a non-malicious incident setting, cascading impact strongly correlates to incident duration, as well as to an organization's IT architecture and the controls available to provide containment.

The elements of the business addressed by extent in this research were business processes, IT systems, metadata (types of data), and personnel. Extent presentation at the incident summary level of the visualization provided a capsule overview of the impact on these elements, which were treated as strata of discrete business operations strictly

showing impact within the layer. The detail screen for extent was designed to show the impact of each layer, as well as how the layers interrelated. Given the cognitive and interactive complexity of attempting to understand how the business operations strata tied together, the capsule review in the incident summary was intended to serve the immediate need for an initial overview that could be investigated further, if desired.

Urgency

Urgency was an attempt to measure the importance of the IT incident to the business. Field study participants used the term "urgency" often. Urgency was a concept leaders considered seriously when determining the level of resource commitment and the desired pace of resolution. Though business risk was certainly a factor, up to this point urgency was a subjective measure that did not appear to be based on established criteria. This research proposes that urgency be computed and treated as a vital statistic. The objective was to make the urgency measure an unambiguous time-varying summative value leaders could rely upon to form an IT incident appraisal on which to base decisions and perform judgments. Unlike priority, this incident attribute was meant to be an objective measure that reflects risk. Priority is a relative measure of importance across a collection of choices and is based, in part, on subjective judgment. Urgency is meant to inform the prioritization process. No matter what other business priorities may be occurring simultaneously with the incident, the risk an incident poses is inherent to the incident.

Urgency was composed of three areas of contribution. The first was the response execution risk that conveyed the project management-oriented risks associated with closing the incident. (Three subcomponents of project risk were scope, resources and schedule.) The second area was direct-cost risk, and the third was an area called impact concerns. There are three broad impact concerns that an IT incident raises, namely brand, compliance and security. These concerns are somewhat abstract in today's com-

puting environments, and would need to be assessed manually by qualified personnel. The components of the response execution risk were rated on a nine-point scale and averaged to compute the response execution risk value. The impact concerns were also rated on a nine-point scale and averaged. For this research, a weighted geometric mean was computed on the direct-cost risk slopes between adjacent projected-cost risk values at five points of time in the future (i.e. +1, +2, +4, +8, +16 hours). The three contributing averages were then averaged together to produce the urgency value. A fully vetted algorithm for urgency was beyond the scope of this research, but an interim algorithm was needed to build coherent displays and related data.

A visualization that can adequately present these five incident attributes should provide a leader with much of the information needed to develop a functional mental image of the IT incident. Another benefit of having these attributes presented in an accessible and repeatable manner is the ability of leaders to communicate more efficiently through the reduction of ambiguity originating from inconsistent access and description of incident details that commonly occur during larger incidents today.

4.3.7.9 Content Group: Response Awareness and Management

Explicit vs. Implied Response Plans

Complex, unusual, costly, compromise, noncompliance, tarnished reputation, disruption, disclosure: all are terms that can be associated with the class of IT incidents being considered in this research. One unifying element of all IT incidents, however, is that they are unexpected. One typically prepares for the unexpected, but it is challenging to schedule it. Dedicated first responders train for a variety of situations. In large IT organizations some of the response team are seasoned, but some will be involved who are not frequent responders. The composition of the team varies by the nature of an

incident, and response objectives can be set out in advance. But while there are patterns of response that can provide the basis for response procedure, response actions vary with the situation, which often is fraught with stress, uncertainty and confusion.

Prepared first responders have a "playbook" that an Incident Coordinator will work from. If there is no procedure that fits, or if the current action plan no longer appears appropriate, the Incident Coordinator adapts to the circumstances. A fire brigade is on location, equipped with communication devices that allow the commander to monitor and adjust the response[71]. But how does an ad hoc IT incident response team coordinate when located on various floors, in various buildings, and across various cities and countries? How do those with business operations responsibility gauge response progress and prepare or compensate for disruptions to their operations? In some cases a "war room" is established or an operations center has the necessary facilities. But that means people have to relocate to share a common image or mental model[72] of the IT incident's character and corresponding response. When relocation is not feasible, web conferencing and enterprise portals are utilized to deliver awareness updates at potentially significant time-cost to those providing the awareness update. As the senior fire official, Davis notes his need to witness an industrial fire firsthand in order to make critical decisions [71]. But unless a physical event such as flood or fire causes an IT incident, the incident produces few external stimuli that a person might assess through his senses alone. Indeed, an IT incident may involve components hundreds of miles away from the incident response team. The primary benefit of proximity is communication and coordination, as well as compensation for the limited access to IT incident-monitoring software and awareness.

The sequence of response actions or response plan is a key component of the incident context each person involved attempts to establish. Instead of verbalizing the plan, the visualization presents a centralized, comprehensible plan of response. And, instead of relying on every responder knowing the same playbook, and ensuring they are executing the same play, each responder can access the "play" or plan online. If changes to the plan

are needed, the plan can be updated and the new information shared with the responders.

Adaptable

The response plan must be adapted to the nature of an incident. The Incident Coordinator and others responsible for prompt remediation will assess the nature of the incident and plan accordingly. There are overarching phases a response transitions through, including "Assessment," "Planning," "Response" and "Recovery." Assessment is the phase in which the nature of the IT incident is characterized. Planning is the phase in which the Response plan is formulated. Response is the phase in which the extent of the IT incident is contained, malicious activity is halted, and available interim solutions are implemented. And Recovery is the phase in which the affected environment is returned to its pre-incident operating condition.

The Assessment, Planning and Response phases are typically the most time-sensitive. However, the robustness of an interim solution implemented in Response may affect the urgency with which the Recovery phase is executed. Closure does not occur until Recovery is complete. In reality, planning is needed for every phase. An improperly executed Assessment may result in an incomplete or erroneous understanding of the IT incident, thus resulting in improper Planning and Response. The duration of each phase is variable. The Planning phase is likely to be the shortest, and it is possible this phase may be executed informally or within a seamless transition from Assessment to Response. Plan design interfaces were reviewed during design, but not considered vital for the evaluation.

Approval

In cases in which IT incidents can be addressed in a straightforward manner (e.g. hard disk failure of a server), the execution procedure involves little risk and needs no

implementation oversight by a leader. However, when an IT incident has had meaningful impact or has been deemed to represent significant imminent business risk, leaders need to know of and approve the response plan. The actions, resources and timeframe all have the potential of both prolonging the incident's impact and increasing its severity. A documented plan is much easier to share, and ideally understand, compared to one that exists solely in the mind of the response coordinator. Plan approval was part of the workflow considered in the visualization's design. Given the constraints of the evaluation, however, it was not implemented, as it was unreasonable to expect an experienced leader to interpret a response plan sufficiently to competently adjust, approve or deny a plan related to an organizational environment they had only minutes to absorb, and using interfaces on which they had received minimal training.

Progress and Projection

Having established a plan, it became practical to communicate response progress and project response timeframes, "progress" including the status of completion of past tasks and ongoing efforts on current activities. "Projection" involved estimating the start time of tasks, and how much longer a phase and, subsequently, the IT incident overall was expected to last. From progress and projection a leader may assess the effectiveness of the response as well as consider adjustments. It may be necessary for a leader to add additional resources, or possibly remove or reassign resources. The visualization was designed to provide this information in various contexts. On the Incident Summary, the user could find high-level response progress by observing which response phase had been started. Projection was indicated in part by showing the anticipated start times of future response phases. The "Response Resource Tasking" screen provided operational, completion and pace status for each task within the plan. Completion indicated progress graphically with a progress bar. Pace – the actual speed at which a task is being executed

compared to expected speed – was indicated by one of a set of icons (i.e. slumped figure with a cane (slow), walking (nominal), and running (ahead)). The graphical version of the response plan presented in the Response Summary indicated completion by accenting the task object within the activity diagram, such as a graphic with a checkmark. Displaying the tasks in the sequence in which they were to be executed provided logical projection. A projected start and completion time were provided textually when a task object was selected from the graphical layout. The "Timeline and Dependency Awareness" screen used a task progress bar to graphically indicate progress by task. Within the timeline and dependency graphic, projection was conveyed by the width of a task object or aggregate width of a set of objects across the timeline.

Although formal progress forecasting models were not within the scope of this research, a simple method was needed in order to populate the fields with reasonable values. By establishing a response plan for a given phase, a critical path was established for that phase. The projected length of the critical path was used to compute the expected duration of a phase. In addition, a task's presence within the critical path was indicated textually and graphically throughout the response-oriented screens.

Response Tasks

A response plan is a structured collection of tasks. Much of a response is oriented to activities that lead to closure of the incident. There are key judgments and decisions needed throughout the response. These decisions or judgments are essentially tasks. Unlike the many judgments and decisions technical responders make while executing an action task (e.g. "Does the server's error log show unusual error entries?"), the explicit judgment or decision task within the response plan was one that required authority. Authority is necessary because the decision or judgment may have one or more business-sensitive implications such as response costs, business operations interruption,

operational risks, additional incident-impact duration, regulatory compliance, or legal liability. In some cases, these require a single person to make a decision; in others, a group of people may share responsibility for the decision. In a dynamic situation such as incident response, some decisions or judgments can be implicit, unless deliberately made (e.g. the completion of a task may be at a pace slower than needed). If no explicit decision is made regarding facilitation of the task, the implicit decision will be to not alter the composition of the team executing the task. With response monitoring, leaders can be vigilant to response challenges that otherwise might not be addressed.

One reason to have the decisions presented in the plan was to communicate to all that they must be made. An explicitly planned decision can be assigned to the proper level of authority and give that leader notice of the upcoming task. This anticipation may allow the leader to be better prepared to execute the decision or judgment task. In an environment in which multiple people are assigned functions, role-based decision assignment may prevent the unavailability of one person from impeding the response. Currently, escalation is one way to get a decision addressed if the original assignee is unavailable. Availability-oriented escalation is reactive and usually time-based, thus requiring a delay to occur. If another person within the role can perform the task, then a single-queue, multiple-server condition has been established, thereby reducing the likelihood of delayed task initiation resulting from availability constraints.

One degree of freedom within the response is the time it takes to complete precursor tasks of a decision task. One impact of this dynamic is that the anticipated time at which this decision is to be performed can shift. By having the decision specified in the plan, it is feasible to update those responsible with a new timeline for making their decisions.

The response planning devised for this visualization calls out the decision and judgment tasks that may be anticipated. In some cases, anticipation may be only moments before the decision must be made. In a truly functional visualization, the response-planning interfaces would need to be sufficiently convenient so as to quickly insert deci-

sions into the task flow as the need for them is foreseen.

Another benefit of formalizing the decision and judgment tasks of leaders is that the visualization can update those who need to know the outcome of the decision or judgment. This formalization of decision-making also documents these decisions, thereby better enabling post-incident analysis and process improvement. This additional accountability may hinder or alter a leader's decision-making methodology[62] due to professional or liability concerns, but that business management challenge will be left to others to consider.

The response plan was presented to users as an interactive diagram oriented primarily toward the logical sequencing of activities. In order to improve recognition of the diagram's conceptual objectives, the diagram format followed the activity diagram approach. According to Hoffer et al., the activity diagram has been used to describe the logical sequence of activities of a business process and accommodates conditional logic that influences activity flow[73]. Unlike Hoffer, though, the conditional or branch step is given equal visual weight as the activity tasks themselves. The conditional step is essentially a decision. The diamond shape used in the activity diagram was expanded and annotated with decision-task information. For the sake of consistency across the visualization, the diamond shape was reused to represent a decision task.

A secondary visual effect was to show progression. As the response progressed relative to the plan, the visual attributes of the activity diagram task objects changed. The interactivity of the response plan diagram provided the user access to the many attributes of a task that could not be presented on the activity diagram directly. In essence, the response plan became a task directory that used task sequencing as an organizing principle. By interacting with the response plan task object, one could access task attribute updates.

Timeline and Dependency Analysis

Response to an incident involves choreographing a limited set of resources in order to execute the response plan. According to Lacey, Hulmut von Moltke, a German strategist, has been known to say, "No plan survives contact with the enemy" [74]. In all but security incidents with an active malicious actor, IT incidents tend not to compensate in response to responders' efforts. However, task-completion estimates may be considerably inaccurate in actuality. This may cause a resource to be inadvertently assigned to multiple simultaneous tasks as a result of a task extending beyond its anticipated completion time, thus overlapping with another task. A resource's lack of availability may delay start of a task. Tasks that span over a shift change could experience disruption as exiting personnel anticipate their departure and arriving staff attempt to engage with the task moments before the previous shift departs. These logistical challenges impact the effectiveness of the response.

A time-based view of the response plan was designed to allow a user to see both the logical progression of tasks as well as the tasks' span over time. Task completion was another attribute visible for each task. Task shapes were roughly consistent with those used in the stylized presentation of the activity diagram previously mentioned. The design attempted to direct the user's attention to tasks experiencing, or those about to experience, logistical challenges by exaggerating the object dimensions within the interactive graphical layout. The graphical layout was strongly influenced by the Gantt chart, due primarily to its pervasive use in project management. One modification was to extend the Gantt metaphor to better distinguish task ordering that is due to resource assignment from progression due to logical ordering. For simplicity, the assumption was that a task was sufficiently engrossing to require exclusive attention of the assigned responders. By showing resource-based progression dependency, a leader could attempt to shorten incident duration by assigning the task to alternate resources. This metaphor helps leaders make time-cost tradeoff evaluations. To accommodate organizations that

rotate responders on a shift schedule, the shift change was clearly marked on the timeline, allowing users to see which tasks might experience shift disruption.

The timeline and dependency graphical presentation was interactive. Similar to the interactive activity diagram previously mentioned, the task objects within the Gantt-like diagram were controls that allowed the user to access task attribute details. Among the details were attributes related to the logistical challenge indicators that may have been raised for the task.

Although not implemented in software, the concept was that, as the response plan was constructed and effort estimates assigned to tasks, the tasks would automatically be laid out across the timeline. As the various tasks' timing and resource attributes change, the timeline and dependency presentation adapts. A graphical shortcoming of the Gantt-like metaphor was that, by assigning time to the horizontal dimension and depicting task dependency consistent with the Gantt paradigm, the graphic's dimensions could not be contained within the limited dimensions of the space provided. An interactive zooming function or overview sub-screen could possibly have helped with navigation. A conceptual shortcoming of the Gantt chart is that it follows a "waterfall" project management metaphor, so returning to a task after it has been completed cannot be accommodated; instead, a new instance of the task is constructed and placed further downstream. Task iteration should be expected, especially for complex IT incidents that have yet to be contained. These limitations prevent this display concept from being the exclusive presentation of the response plan.

4.3.7.10 Content Group: Information Support

A number of decisions were collected from the field study investigation. When analyzing the decisions for their information requirements, it was determined that well-considered decisions needed information beyond the specific context of the IT incident and its corresponding response. Essentially, the decision-maker needed institutional

knowledge. Given the ad hoc nature of team composition and the "as needed" basis for many leaders' participation, it was not clear that new leaders or those who respond only intermittently have sufficient background or context for the decisions they are asked to make. Furthermore, those who are well-versed in institutional details may not be aware of changes that may have taken place. The Information Support content group was designed to address gaps in a leader's understanding of the institutional context. Those leaders with no need for this information could simply ignore the functionality by avoiding related screens.

The Information Support content group consisted of information related to cultural, organizational and technical topic areas. A design consideration (not implemented in the prototype) was that information from those topic areas presented at the top-level screen could automatically be filtered to present information relevant to the incident being addressed. A user could then access a broader range of information if he desired a broader context. This content group was designed with a summary-level screen and supporting detail screens, providing richer content and interactivity for topics under focus. Only the top-level summary was implemented, as there was little evaluation benefit beyond allowing an initial exposure to institutional knowledge access. Although additional interactivity and knowledge details would be beneficial operationally, the evaluator would not have gained a significantly deeper appreciation for having this richer access within the narrow time frame of the evaluation. In fact, the time spent on extraneous details could have caused additional stress as evaluators satisfied their curiosity but made little progress toward accomplishing the evaluation tasks assigned.

The cultural topic area was assembled to provide a view of underlying principles and objectives the institution is seeking to achieve or uphold. This context helps the user gauge what a "culturally correct decision" would be in the eyes of his or her superiors and other stakeholders. The topic area consisted of two topics, "Business Dynamics" and "Policy and Procedures." Within the Business Dynamics content topic a user could

find the stated institutional values, financial considerations and institutional goals. The Policy and Procedure topic was a convenient view into the policies, procedures, guidelines and standards approved by the institution. This topic area may not be consulted often as a decision is being made, but it does allow the leader to review the cultural dimensions when needed.

The organizational topic area was assembled to provide access to the current state of the institution's internal organization, as well as human resource information regarding those who work for it. This helps a leader understand the lines of authority, the affiliation of personnel within organizational units, and the geographic and specific office locations of the organizational units. In a sense, the organizational structure provides a leader a convenient view of the "social architecture" of the institution that may influence communications and other decision-making. Human resources information provides a leader with contact and skills information for personnel who may not be familiar to the leader. Ideally, the human resources data set would tie into work schedules and work-status tracking. This additional information may help a leader choose a new member of the response team as well as understand the scope of the personnel actually affected by the incident. Although physical safety is rarely a consideration in IT incidents, it is nonetheless possible that personnel may need to be accounted for in an emergency situation.

The technical topic area was assembled to provide access to the current state of the technical aspects of the business. The topics identified were "Regulatory Profile," "Business Process Architecture," "IT Architecture," and "Change Management." The first three topics help a leader to determine the technical backdrop of the inner workings and constraints governing normal operating conditions, as well as those that may influence decision-making during an IT incident. Change Management provides insight into the decisions related to changes in IT operations. The first question of troubleshooting is, "What changed?" Cebula and Young located the risks associated with "Actions of

People" as the first top-level category and "Inadvertent" (containing the "Mistakes," "Errors," and "Omissions" third-level categories) as the first sub-category in their taxonomy of cyber-security risks[75]. Having convenient access to Change Management records may provide insight into the possible inadvertent or procedural causes of an IT incident. Significant doubt and stress can be dispelled when an IT incident can be confirmed as a non-malicious event.

The top-level screen called "Information Support Center" was implemented as a multiple-panel portal providing simultaneous access to many of these topics. The panels were collapsible in an accordion control, thus allowing some flexibility in the space available to a topic. The topics of Business Process Architecture, Policy and Procedures, Human Resources, Business Dynamics, and Change Management were presented primarily in tabular or textual form. Controls were provided that allowed data to be filtered. The IT Architecture and "Organization Structure" topics were addressed primarily in graphical form, with fairly traditional topology, systems and dataflow diagrams, organization charts, and site plans used to display that information.

4.4 Discussion

This section provides brief reflections on an IT incident management visualization system, as well as a self-critique of the design.

4.4.1 Operational Adoption

A factor that may prevent adoption of an IT incident management visualization system is a lack of necessary authoritative data sources. With integration technologies such as web services, facilitating data feeds from diverse sources into the visualization is feasible. An organization would need to invest in maintaining an accurate and detailed institutional knowledge base, enable responders to provide progress updates, and inte-

grate various monitoring systems that provide operational status as well as characterizing the IT incident. Additionally, although visualization can be shown to be of value, the necessary organizational level and personal workflow changes would require consensus building and steady support by upper management.

4.4.2 Choosing Silverlight

The design choice of developing the visualization in Silverlight was motivated in part by the popular desire to avoid installing and maintaining desktop applications. By developing a rich information application that was web browser-based, this objection to the visualization's benefit was avoided. One constraint of this execution environment was that only a single screen could be displayed at a time. A developer of a proper Windows application would have the option to support multiple windows accessible on the screen. While introducing usability challenges, this multi-window flexibility would also allow the limitations of one window's content to be supplemented with another window positioned in close proximity. In the Silverlight environment, a second browser session is needed to achieve this effect. As facilitating multiple simultaneous sessions by one user was outside the scope of this research, an inconvenient screen layout choice could not be easily overcome by a user-initiated workaround.

4.4.3 Understanding Cognitive Fit

Although the concept of cognitive fit was considered throughout the design, there were no specific IT incident-handling requirements necessitating its consideration. There is no obvious reason to believe cognitive fit is irrelevant to the broad range of tasks leaders perform within IT incident management. An exploration of cognitive fit within the IT incident management task domain is needed. This exploration has been facilitated in part by having an established baseline of visualization capabilities. Until then, it is unclear whether the cognitive fit support provided is appropriate and effective.

4.4.4 Waterfall Project Management

Response planning is essentially dynamic, short-term project planning. Other than for a bit of iterative support, the project planning technique chosen essentially followed a linear sequence of task execution commonly called the "waterfall" model in software development. There are other project management techniques. But unlike traditional project planning, the scope, schedule, cost and resource dimensions of IT incident response can change instantly. More dynamic project planning paradigms, such as agile project management[76][77][78], may be more appropriate for IT incident handling. Response planning is a content layer on which much of response monitoring and action enablement anchors. It is possible that supporting an "agile" response plan would require alterations to the presentation structures used to depict the various response-monitoring dimensions.

4.4.5 Effort Estimate Verification

Estimating the effort a task may require is by nature an approximation. A non-expert who is familiar with a task may estimate a task's level of effort with a greater degree of inaccuracy than an expert. Allowing for the time estimate to be qualified with a degree of uncertainty was strongly encouraged during the field study. In essence, this is a means to alleviate "analysis paralysis" among planners who are inexpert or otherwise unable to anticipate the "ground truth" that may be encountered. A suggestion was that a more qualified person could later review the estimation and adjust it accordingly, subsequently decreasing the degree of uncertainty. In longer-running incidents, the accumulation of poor estimations could significantly misrepresent the likely duration of the incident and its response phase. In an operational setting where response plan approval is required, qualified personnel could be allowed to adjust task specifications after leadership had approved the logical sequence of the response plan.

4.4.6 Granularity and Type of Direction

Response planning is necessary. Beyond a certain point of sufficient guidance lies a point of diminishing returns. Extra time spent on planning is, potentially, time not spent by planners executing the response or performing other functions. The task granularity at which a plan is defined is an open question.

An overly detailed plan may not align with the challenges at hand, and will likely require more time for a leader to interpret and approve. Another consequence of fine granularity is that technical responders will have to update more task elements to satisfy communication and coordination needs. The plan will never be applicable again, thus hindering an organization's ability to develop reusable response patterns for future incidents. Ideally, there is a level of sufficient granularity that gives technical responders practical direction and coordination. Additionally, leaders who are monitoring response assess the fit between the response and the incident. Insufficient or incomplete guidance may prevent effective response and possibly exacerbate the incident's impact.

In their research into hierarchical decision-making, Clancy et al. identified two command styles, i.e. "Action" and "Intention"[79]. In essence, the plan is a documented series of commands. A response plan populated with tasks expressed in the form of specific actions to be performed would be similar to the Action command style. A plan containing tasks expressed as intentions or objectives would be similar to the Intention command style. An Intention-styled plan would allow technical responders to exercise initiative and flexibility to adapt to the actual conditions of the incident. But while an Intention-styled plan may prove more readily reusable, it may complicate effort estimation.

4.4.7 Response Action Evaluation

The current implementation of the timeline and dependency graphic presentation is static in terms of task ordering. This is primarily a limitation resulting from development

resources and time constraints. Option exploration is an important part of decision-making. A natural extension to the implementation would be to allow a user to directly manipulate the task object in order to facilitate "what-if" analysis regarding logistical considerations. Various logical and logistical constraints would have to be enforced to avoid a user proposing an unreasonable alternative plan. In time, the visualization might identify common task reordering patterns that could compensate for downstream inconsistencies arising during "what-if" considerations.

4.4.8 Expressions of Extent

In the current design, extent has been addressed by graphically displaying the impact of the incident across the various business elements. Summative values describing breadth and degree of impact may be of value. It is difficult to communicate extent between people or to develop numerical algorithms that would incorporate the extent incident attribute while it remains a strictly graphical description. As use cases develop for the numerical representations of extent, the form and means to produce these values will likely become more apparent.

4.4.9 IT Incident Escalation

Incident escalation is the transfer of response control authority to a person or group with higher organizational authority and responsibility. Business risk and visibility (e.g. attention by employees, customers, regulators, investors or others who may adversely affect the business) are two parameters that would influence escalation. Escalation is an important decision in the life an incident, as a mismatch between the characteristics of an incident and the involved leaders' authority, business understanding and training may lead to greater losses for the business, not to mention legal liability. Escalation considerations were factored into the design of the Incident Coordinator screens, but implemented support was limited to referencing escalation as a vital statistic. Given the

limited time available in the industry prototype evaluation for immersion in the business context, escalation decision tasks would have been very difficult for an evaluator to perform competently.

The field study did not explore the nuances of escalation sufficiently to compile a reliable set of general criteria and workflow surrounding escalation and de-escalation. Additional field study is needed to collect information regarding escalation parameters and associated workflow. Until then, it is difficult to develop effective visualization support for escalation and de-escalation.

4.4.10 Incident Awareness Overview Design

When laying out the IT incident attributes in the Incident Summary screen, it was a challenge to include the entire set of incident measures on one screen. Choosing to represent IT incident extent graphically was costly in terms of screen-space consumption. This was unfortunate, because the IT Leader cannot achieve a comprehensive understanding of the incident without switching between screens. Thus, highly related information is, as Tufte would describe, "stacked in time" ([80],pg. 81), failing to leverage the opportunity, per Tufte, to unify words, numbers and pictures that allows the user "... to understand and to reason about the materials at hand, and to appraise their quality, relevance, and integrity" ([81],pg. 83). In a redesign of the Incident Summary screen, a priority would be to locate all key IT incident attributes in a common field of view.

4.4.11 IT Incident Duration Timer

Time is a pervasive measure of the incident, and was reported in numerous contexts within the visualization. Despite efforts to provide sufficient support for time, a field study member raised a deficiency during prototype testing: the prototype lacked an indicator showing how much time had elapsed since the incident started. The incident's initiation timestamp was readily available, but it would require the user to perform a

mental or manual calculation to determine how long the incident had been active at the current point in time. An IT incident duration timer would have provided a vital incident attribute. As such, it should be accessible on every screen relevant to the incident. Unfortunately, it was not possible to accommodate this suggestion for the industry evaluations.

CHAPTER 5. PRACTITIONER–ORIENTED EVALUATION FRAMEWORK

This chapter discusses the reasoning and purpose of the evaluation framework designed to facilitate validation of the research conducted in Chapter 3 and Chapter 4. The substance of the design is presented as well. Furthermore, execution of the evaluation events is described.

After a brief introduction, this chapter will begin with a description of the relationship between the Iterative Field Study Methodology and the evaluation framework. The next section will explain the relationship of the IT Incident Visualization System design to the evaluation framework. An overview of the evaluation strategy is provided in the third section. The "Evaluation Purpose and Requirements" are discussed in the fourth section, followed by a section that explores the Practitioner–Oriented Evaluation Framework. The chapter closes with a brief section of observations in the discussion section.

5.1 Introduction

As a matter of proper scientific inquiry, it was necessary to perform independent observations and take appropriate measurements in order to objectively evaluate the research accomplished in the field study stages prior to the Industry Public Evaluation stage. The nucleus of this research presumes the hypothesis stated in Section 1.4. The hypothesis is difficult to test directly.

A relevant problem domain containing security and compliance decisions was in-

vestigated, and a dynamic visual or visualization system was constructed in order for independent observations to be performed. In this research, independent observations required human interaction and subsequent evaluation to be captured; therefore, the terms "independent observation" and "independent evaluation" or "evaluation" are used interchangeably. The human in this context is a business leader experienced in the selected problem domain. As matter of coincidence and a possible source of confusion, the problem domain research uncovered a role commonly referred to as "Business Leader," a description of which can be found in Chapter 3. The "business leader" referred to in the research hypothesis should be interpreted as a generic term, which is defined as, a person who has responsibility and authority to make decisions or exercise judgment on behalf of an organization regarding IT incident management matters that affect business impact or risk. As a matter of problem domain selection and investigation, as well as iterative restrictions in research scope, the business leader determined most appropriate to perform an independent evaluation was one who had performed the role of an IT Leader in one or more IT incidents. Given the cognitive nature of awareness and comprehension, the primary measurement tool chosen was the survey instrument.

This chapter is devoted to the framework developed to conduct multiple independent evaluations in a repeatable and reliable manner with independent IT professionals. Independence was primarily a concern regarding prior knowledge or familiarity with this research, as well as with the principal investigator. Given the nature of the sampling or recruitment challenges, independence of judgment and anonymity between evaluators at an evaluation location could not be assured.

5.2 Iterative Field Study Methodology

The evaluation framework was designed to facilitate execution of the final stage of the Iterative Field Study Methodology. The goal of seeking out independent profession-

als required the framework to provide the context, usability and content sufficient for someone prepared with only their personal IT incident experiences to quickly absorb the purpose of the evaluation, perform hands-on activities, and evaluate the broader value of the visualization.

The IT incident context and evaluation tasks selected for the evaluator were in large part influenced by the stages that led up to the prototype development. Any potential misalignment between evaluation tasks and the evaluators' expectations was a concern. This affected both the likelihood that evaluators had prior experience with executing equivalent tasks in actual IT incident settings as well as the sense of reasonableness of the tasks relative to the IT Leader role. The evaluation tasks were implemented so the evaluator could perform constructive activities while interacting with the visualization. Frustration and dissatisfaction with the tasks and task performance mechanism could have influenced an evaluator's ability to objectively project a sense of the visualization's value to their professional and employer operating contexts. Because the alternative of either an unstructured exploration or simply "wandering" through the visualization was likely to be far less informative to the evaluator, this risk could not be avoided.

5.3 IT Incident Visualization System

The visualization prototype design and functionality governed what could be evaluated as well as how[82]. The evaluation framework had to be tightly integrated with the prototype both in terms of evaluation task objectives and task completion choices in order for the evaluator to successfully perform each evaluation task. The interface structures and types of data designed to facilitate task completion were subject to the data structures and dependencies introduced in prototype development.

On the other hand, the evaluation framework strongly influenced the prototype design. In order to provide the necessary information and affordances to complete the

evaluation, evaluation interfaces needed to be accessible to the evaluator. This accessibility introduced constraints on the prototype's design. Fidelity with which the prototype was developed was targeted to the evaluation audience. Operational professionals were expected to have a greater bias against a prototype lacking the completeness and polish that is found in their production-grade tool sets.

Overall, the cross-influences between the evaluation framework and the visualization prototype were numerous. Despite that, these were two distinct research challenges. As mentioned in Chapter 4, the prototype's design was not constrained to support only the IT incident fabricated in the evaluation framework. Among the software aspects of the evaluation framework, the concepts introduced to facilitate evaluation were not dependent on the target of evaluation being an IT Incident Visualization System prototype.

5.4 Evaluation Strategy

This section provides a synopsis of the evaluation approach explained in detail in the sections that follow. This summary structure reflects ideas from Treu[82] and Stone et al.[83] that suggest a concise means to describe the evaluation approach.

Table 5.1: Dimensions of the Evaluation Strategy

Evaluation's Purpose	To determine if the visualization prototype is able to improve business leaders' awareness and comprehension of information security and compliance decisions.
Sources of Evaluation Data	Primarily from targeted users (i.e. IT Leaders), secondarily from surrogate users who were experienced IT incident handlers with no IT Leader role experience, and yet are able to emulate the IT Leader role.
Evaluation Objectives	Determine what aspects of decision-making, if any, were facilitated by the visualization from personal and collective points of view.
Evaluation Scope	Primarily, the visualization elements emphasized by the evaluation tasks; secondarily, the remaining elements evaluators encountered while executing the evaluation.
Type of Evaluation	The study is primarily a descriptive study to determine if and how decision awareness and comprehension is improved.
Data Collection	Primarily, the data are subjective data self-reported in self-administered paper questionnaires. Secondary data are collected in activity logs to provide context to the self-reported data.
Evaluation Target	A medium-fidelity prototype with minimal graphical algorithm support and static pre-determined data sets.
Constraints	Evaluations must be convenient, brief and engaging to the IT professional. They must also be relevant, reliable and repeatable, and avoid introducing data bias. Despite the quantity of potentially targeted users, access to them as well as their willingness and availability will influence the size and quality of the evaluator pool.

5.5 Evaluation Purpose and Requirements

The primary purpose of the evaluations was to validate the hypothesis stated in Section 1.4. Underlying this objective were practical requirements that had to be addressed in order to gather information that either proved or disproved this hypothesis.

As mentioned in the "Introduction," the targeted evaluators were independent pro-

fessionals with IT incident-handling leadership experience. Convenience was a significant requirement. These people had limited availability over the course of a week, and were easiest to access during the workday. Also, as the amount of time requested away from work further restricted their ability to participate, limiting the time an evaluator was asked to invest was also necessary. Engagement by each participant was essential when they did participate in order for them to effectively respond to questionnaires, achieve an understanding of their purpose, become familiar with the research and perform hands-on activities on an interface they had never seen before.

Convenience, time limitation, and engagement are the three key requirements facing the evaluator. The background requirements necessary for research data quality were relevance, reliability, repeatability and bias avoidance. Although efforts were made to minimize the effect of bias on the results, bias was inevitable[84]; however, not all biases were equally detrimental to the data collected.

As a consequence of the convenience requirement, the evaluation had to be conducted in multiple locations. This naturally resulted in portability and transportation issues. Within computer design, portability is often a tradeoff with computing performance. The entire ensemble of equipment and supporting materials needed to be efficiently and safely transported to and from both an evaluation facility and the actual evaluation room. Convenience was also a factor from the hosting entity's perspective, with efficient logistics in order to minimize the hosting entity's effort.

All of these high-level objectives were considered in the evaluation framework design elements, as well as in the evaluation execution discussed in the upcoming subsections.

5.6 Evaluation Framework

5.6.1 Evaluation Event Objectives

Initially, the total time allocated for evaluator participation was one hour, excluding travel. The basis for time allocation was that an hour was a reasonable amount of time a professional might be able to spare away from work. This was later modified slightly to 75 minutes in order to accommodate the actual lengths of the training video and introductory presentation. The time allocation illustrated in Figure 5.1 is a reasonable depiction of the proportions of time allocated for the various research activities taking place at an evaluation event.

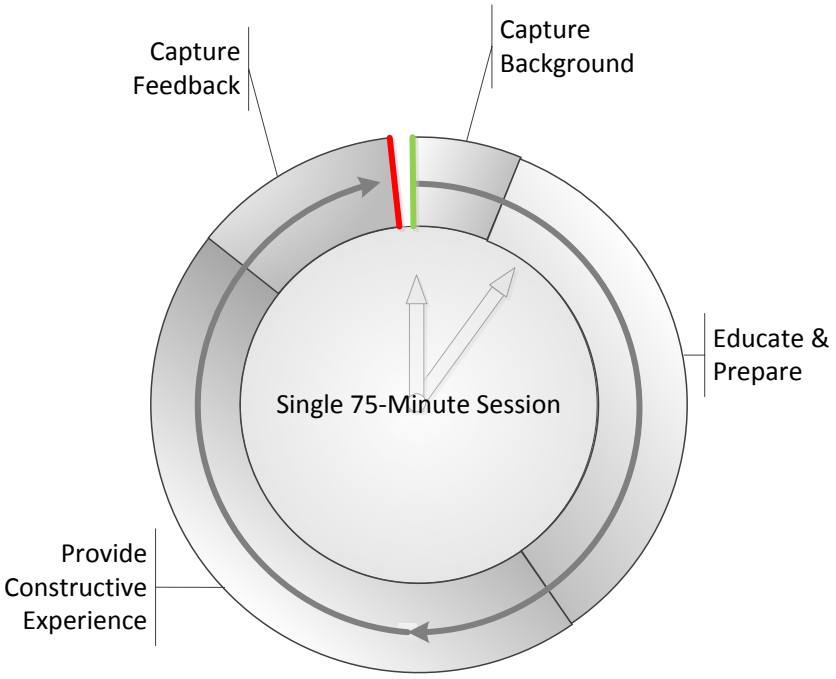


Figure 5.1: Evaluation Event Objectives

Numerous components needed to be designed and integrated in order to achieve all of the evaluation-day objectives in a reliable fashion. A self-administered survey instrument was needed in order to capture an evaluator's background quickly and efficiently. Also, a couple of education approaches were needed in order to bootstrap each evaluator to

the point they could start performing evaluation tasks. The first method was an in-person presentation and the second was an individually controlled viewing of a training video. The third objective, constructive experience, was the most technically elaborate aspect of the evaluation. A quick synopsis of the design considerations can be seen in Figure 5.2. Finally, a second self-administered survey instrument was needed to capture post-experience feedback while the evaluator's experiences were fresh. The administered versions of the survey instruments can be found in Appendix A.

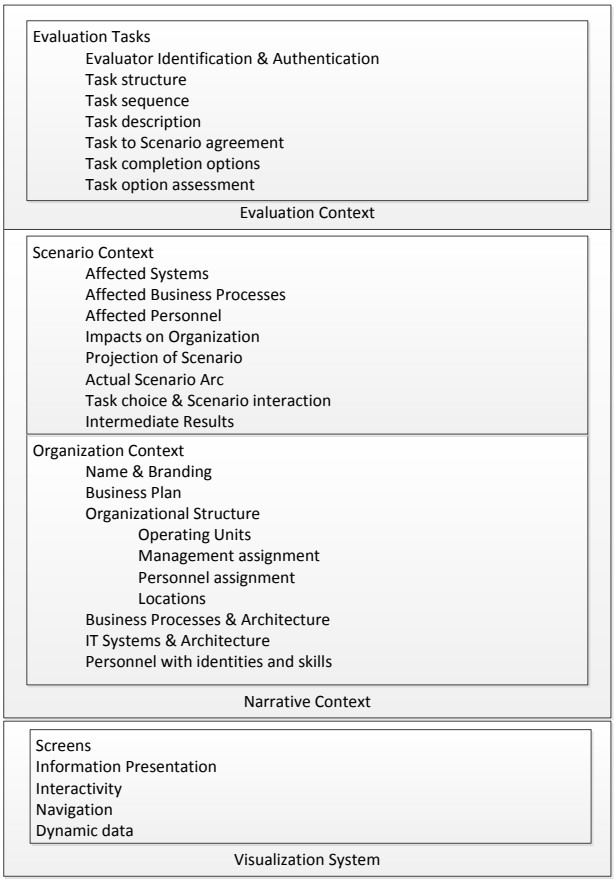


Figure 5.2: Design Elements for Hands-On Evaluation

5.6.2 Framework Elements

The components developed for the evaluation were organized around each of the evaluation objectives depicted in Figure 5.1.

5.6.2.1 Capture Background

The capture of evaluator feedback on the prototype would be incomplete without the ability to ascertain the background influencing opinions reflected in the feedback. Although calls for participation specified the desired qualifications, it was not clear what the actual qualifications were of each evaluator as they arrived at the evaluation. Additionally, evaluator backgrounds were anticipated to be helpful with interpreting commonalities of opinion.

The survey instrument was a paper document. Paper was chosen over a computer-based medium primarily for its simplicity of administration and subsequent reliability in performance. So long as a functioning writing implement was available, the survey could be completed. This also simplified the role the evaluation computers played.

The survey was administered prior to any introduction to the research beyond what was available in the "call for participation" literature (an example is provided in Appendix K). This timing was chosen for two reasons: first, to limit the size of the second questionnaire; second, to collect information that each evaluator could provide without offering additional information about the research, thus eliciting responses less likely to be influenced by the research about to be presented.

The numerous choices made in the layout of the instrument were strongly influenced by Dillman et al.[38]. The instrument's design could be disassembled and rationalized, but that would take a considerable amount of space. Instead, discussion is limited to the research contribution sought by the questions that were asked.

The questions formulated were categorized into four sections, as seen in Appendix A, namely "Personal," "Professional," "Organization," and "IT Incident Management Biography." The Personal section requested gender and age in order to collect fundamental descriptive information of the evaluator as a person. The Professional section was designed to collect information about the evaluator's familiarity with information technology and a broad sense of their professional responsibilities, as well as their famil-

iarity with their current employer. Their employer's ZIP code was requested in order to generally locate their workplace, which would be useful in analyzing feedback from a geographical perspective. The Organization section was intended to characterize the size of the evaluator's employer in terms of personnel and the organization's purpose (e.g. pharmaceuticals, federal government), thus possibly providing additional insights into their feedback. The IT Incident Management Biography section was the longest and most complicated in terms of what the evaluator had to consider in order to respond. This last section provided an opportunity for the evaluator to declare their expertise with and function within IT incident handling. Additional questions asked for the magnitude of the impact IT incidents have had from both a personal and organizational perspective.

5.6.2.2 Educate and Prepare

The primary mission of this evaluation objective was to prepare the evaluator to successfully complete the hands-on activity and provide thoughtful feedback in the second survey. To achieve these goals, each evaluator needed an intense introduction to the research, an explanation of their role in the research, and training on how the hands-on environment functioned.

These objectives were divided into two mediums. The first medium evaluators encountered was a presentation provided by the on-site researcher; the second was a video that started after logging in just prior to starting the first task. The presentation was oriented toward establishing the conceptual and emotional groundwork needed prior to starting the hands-on activity. Research suggests that the emotional state of a person affects learning and creativity[85]. In a sense, the emotional state of the evaluator affected their engagement in the evaluation process, a consideration that was integrated into both mediums. The video offered training on how the evaluation environment functioned, as well as what was expected of the evaluator from an activity performance perspective. There was overlap in content between the two mediums in order to provide multiple

exposures to important concepts.

The presentation covered the following topics:

- Presenter introduction
- Sponsor (Information Assurance Center) introduction
- Event purpose
- Evaluator qualifications
- Concerns regarding privacy, voluntary participation and benefits
- Research objective
- Research structure
- Field study findings
- Research purpose of the prototype
- Parameters of the hands-on experience
- Simulated context and IT incident
- Training covering broad layout, logging in, identity/function of fictional character, how to complete an evaluation task, navigation
- Answering questions and providing final reminders and instructions

These topics helped to familiarize the evaluator with the nature of the activity, provide background leading to the subject of their evaluation, set the expectations of what they were to do, provide the narrative context to what they would experience, and offer an initial explanation of the workings of the evaluation environment. From an emotional perspective, the evaluator was able to determine whether the activity was relevant and

worthy of their continued interest in the process. The IT incident management purpose of the visualization's functionality was deliberately avoided, as the limited time allotment did not allow for the possible one-to-three-hour explanation necessary to cover the concepts or intended workflows. As a usability test and capture of first impressions, it was better that design intentions and inadvertent leakage of opinions by the researcher be avoided.

As a medium, the video was highly effective in delivering content in a repeatable fashion. It also can be an effective means to demonstrate functionality and provide an opportunity to orient the viewer to the spatial layout. A personalized viewing was arranged, allowing each user to adjust volume and rewind portions they needed to repeat. The length of the video was a major design consideration as, overall, the video delayed the evaluator's ability to perform the evaluation. More importantly, an overlong video would have affected the evaluators' ability to maintain focus on the content presented. The design of the video was a balancing act between length and content. One challenge was with the speed at which words could be heard on the voiceover, with some research reporting effective listening rates of up to 300 words per minute and more[86][87]. Complex ideas require reflection for effective learning, and testing showed such a pace to sound manic to the listener. An initial completed video had pauses between ideas edited out, and nearly all who viewed that version in dry runs found it very challenging to glean understanding by the end. A second version was produced with pauses introduced between thoughts, but keeping the original word rate of roughly 180 words per minute.

As a means to expand the perception of the size of the research team, as well as set an alternative emotional tone, a woman was selected to perform the voiceover. The voiceover was recorded in a studio and edited by a professional sound engineer. The sound quality was considered important from both emotional and cognitive perspectives. Poor sound quality could distract the listener from the content, as well as imply a sense of low standards that might translate to the ensuing experience. The visual track consisted of

frames primarily showing the developed environment. A bit of MS PowerPoint animation was used to present concepts of the system's structure. In addition to the voiceover, professionally recorded "wash" or "bed" music was mixed in at a low volume to set an energizing tone without being overly hectic or distracting. The video clocked in at about seven minutes.

The video addressed the following topics:

- General layout explanation
- Evaluation interface functionality description
- Content structure explanation
- Prototype navigation explanation
- Prototype screen-layout explanation
- Assurances that a complete understanding of the prototype was not necessary
- Explanation that the incident's outcome depended upon user choices
- Instructions on how to access incident details
- Thank you and mentioning that the on-site researcher was available for questions

Combined with the presentation, the video rounds out the minimal education the evaluator needed to proceed with the hands-on activity. Little time to dwell on the materials was available, and no preliminary hands-on exercises were provided. This situation primed the evaluator to learn "on the job," and was, ideally, sufficiently intense to promote curiosity and excitement, but not so overwhelming that the evaluator withdrew. This process relied on the evaluator being qualified, as the hands-on environment provided minimal scaffolding for bootstrapping an unqualified evaluator.

5.6.2.3 Provide Constructive Experience

It is highly challenging to evaluate a set of visualization concepts in the abstract. Furthermore, attempting to envision its value for personal use or, broader yet, to one's employer, is difficult if no value has been experienced. Even those who are comfortable with abstract and philosophical concepts cannot respond without a long list of qualifications. For example, "Yes, the proposed idea has value, but it would have to contain/ do/ hold/ perform/ appear like this *data/ function/ visual element*." This resulting equivocation has limited value, as no substantive progress would be made toward proving or disproving the research hypothesis.

A visualization system with no data provides little value because, visually speaking, there is nothing for a user to see. Displaying arbitrary data was an option, as the user might possibly derive superficial value in the form of visual stimulus, but higher-order cognitive value would be non-existent. As Card et al. state, "The purpose of visualization is insight, not pictures" ([58],pg. 6). The data contained within the visualization system must be relevant to some established context. The actor using the system must also have context from which to interpret and utilize what is being presented. Without a purpose for utilizing the visualization, there is no concerted effort to seek insight, thus failing to discover any potential value in the research. A constructive experience was therefore crafted in order to prepare the evaluator to respond thoughtfully to the post-evaluation survey, and thereby thoughtfully responding to the research hypothesis as well. The constructive experience consisted of a single IT incident scenario and six evaluation tasks. Each evaluator experienced the same IT incident and was asked to perform six tasks, but slight variation in task composition was facilitated through evaluator selection.

Context Hierarchy

The constructive experience was a hierarchy of context layered over a visualization

system, depicted in Figure 5.2. The context hierarchy was composed of two context area categories. The first was the "Narrative Context," which provided the basis on which the second category, the "Evaluation Context," was constructed. The Narrative Context provided the logical framework on which to build coherent and consistent data that was populated in the visualization system. There were two subcategories within the Narrative Context, the first being the "Organization Context" and the second the "Scenario Context." The Scenario Context was dependent upon the Organization Context. The scenario was the sequence of events the evaluator experienced that could not exist in isolation from an underlying environment in which the events were to transpire. Having a scenario established, the evaluation tasks were formulated to be "practical" and "reasonable" in the context of addressing the scenario. Evaluation task details were relevant to the scenario, but more broadly, each challenge the evaluator faced was something they either could have or had encountered in practice.

Evaluation Task Completion Strategy

Although conceptually each context layer was grounded simply in the layer below, the grounding or coupling of the Evaluation Context and Scenario Context layers within this medium-fidelity prototyping environment was bi-directional. The scenario content was manually generated. A consequence of this limitation was that manual effort was required to ensure reasonable alignment between content and each task, as well as between task choices. The managed alignment required that the mechanics of task completion be restricted, so choice options were well-defined and limited in quantity. Underlying logic within the software environment switched data sets, images and other static layouts as each task choice was made. A side effect of limiting the quantity of choices was that it simplified the task-completion process without overly simplifying the experience with visualization. In many cases, task choices could be vetted simultaneously. Having more

choices for each task beyond those provided would have had limited value. More choices would have decreased the probability of random achievement of the best closure results, but at great expense in content generation.

Narrative Time

The scenario in which the evaluator participated provided views into the IT incident lifecycle as well as challenges faced in addressing the IT incident. Although there are IT incidents in which an entire handling lifecycle is twenty minutes or less, this timescale would be conceptually inconsistent with the tasks selected. Task selection was based on the requirements ranking discussed in Chapter 3. The rationale was that if particular requirements were given preference by professionals in the field study, then the Independent Professionals would also appreciate exercising the implementation of those requirements. Therefore tasks were crafted to exercise those requirements, which lose practical relevance when an IT incident is short-lived. Thus the scenario lasted longer, narratively speaking, than the actual time allotted for the evaluation. In order to accommodate the time-span mismatch, time lapse was introduced and communicated to the evaluator.

Evaluation Interfaces

From the implementation perspective, the evaluation interface was developed first. Since the objective was to have the visualization adapt to evaluation task choices, the state machine that governed the visualized content was embedded into the evaluation interface. A common narrative state was maintained across all of the visualization screens, and changed only after the evaluator made a choice.

The evaluation interface was broken into two narrow regions in order to give the

visualization prototype a flexible aspect ratio. The interfaces can be seen in Figure 5.3. The vertical column on the left-hand side was devoted to monitoring progress through the evaluation as well as the narrative timeframe of the IT incident scenario. The horizontal region on the bottom was devoted to providing information about the current task at hand, as well as enabling the evaluator's task completion. The prototype accepted a range of user input, facilitating interaction with various functions simulating a system able to support IT incident response. Prototype actions taken by the user had no bearing on satisfying the literal interactions necessary for the evaluation to proceed to the next task. Task completion required interaction in the bottom right corner in the "Evaluation Task Description" region.

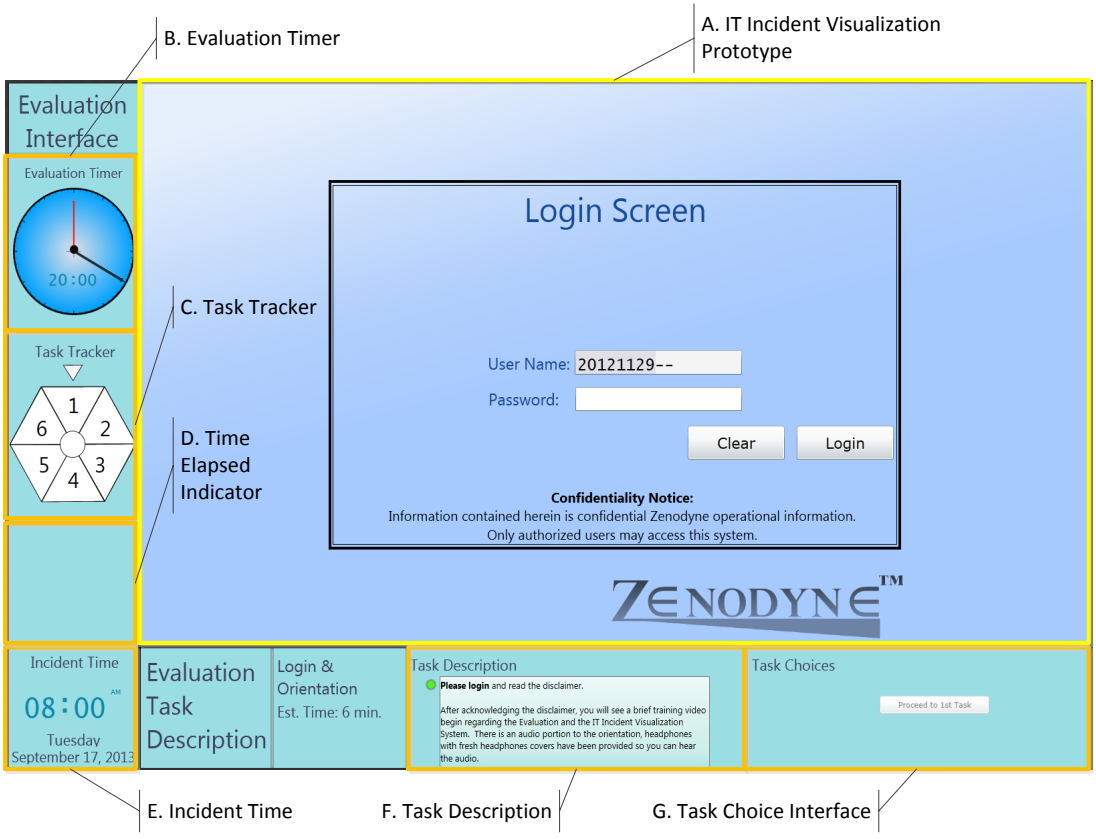


Figure 5.3: Hands-On Environment

The "Evaluation Interface" region had four information elements. The top two elements were related to the evaluation's completion; the bottom two were associated with the scenario. "Evaluation Time" was a countdown timer helping the evaluator keep track of the time being spent performing the evaluation. The "Task Tracker" indicated, by way of shading and animation, the current task at hand, how many tasks had been completed, and how many tasks remained. The "Time-Elapsed Indicator" was a temporary display of the amount of total time elapsed as the evaluator started the next task. The "Incident Time" element was a clock reflecting the current scenario time. After a task had been initiated, the clock proceeded to track time in real time, providing a sense of time passing in the context of the scenario as the evaluator worked through a task.

The primary elements within the Evaluation Task Description were "Task Description" and "Task Choices." The Task Description updated for each task, and provided orientation and instruction sections. The orientation was intended to provide context to the task to be performed. With time lapsing in jumps, together with no interaction with the other members of the response team, it was necessary to provide narrative filler in order to establish context for the task. In some cases the orientation provided organization context (e.g. policy) that would not be known by the evaluator. The instruction section explained what the task was and clarified the significance of the choices presented in the Task Choices area. It was clear, prior to implementation of the visualization screens, that having many prototype screens would likely make wayfinding challenging for the first-time user. To assist with wayfinding, screen navigation controls were provided within the Task Description section.

Task Choices was the section of the Evaluation Task Description in which the evaluator's choices were committed. Mechanically, choices were facilitated by radio button controls, with the choice description next to them. For all but the last task, task six, the number of choices was limited to three. This forced-choice mechanism gave the evaluators clues as to what the best answer might be. By implementing a choice-sensitive,

scenario-unfolding scheme, the evaluator knew that choices were not equal in quality for most of the decisions they were asked to make. Combined with the clues, this motivation provided the user practical goals while seeking out information within the visualization.

Task Sequence

The task sequence was designed to initially provide a gentle start, and end with narrative closure. The first and last tasks were designed to encourage the user to seek out facts that required little interpretation or analysis; the second, third, fourth and fifth tasks were much more challenging. The second task dropped the user into the deep end, asking them to select as well as complete the task. The third task complemented the second task to ensure that each user experienced a similar set of concepts. The fourth and fifth tasks were explicit decision or judgment tasks that affected the structure of the response. Content of the evaluation tasks can be found in Appendix M. The corresponding task-state and narrative-state designs can be found in Appendix L.

Task Option Assessment

In order for the task choices to influence the scenario in a manner that conveyed a sense of consequence for each decision, parameters of the incident and response changed. To help guide the parameter selection, many task choices were pre-evaluated. The pre-evaluated grades were essentially "good," "adequate" or "bad." The significance of the grade was reflected in subsequent IT incident parameters. Typically, a "good" choice resulted in better incident conditions and a "bad" choice resulted in the incident getting worse. This helped to provide a rationale for the final closure results.

5.6.2.4 Capture Feedback

Having completed the hands-on activity, the evaluator was sufficiently prepared to evaluate the visualization from their professional perspective. Feedback was captured using a paper-based, self-administered survey instrument. The layout of the second questionnaire followed many of the conventions used in the first.

The questions formulated were categorized into four sections, as seen in Appendix A. The first section, "Evaluation Experience," captured broad qualities related to what the evaluator had just completed. The first two questions related to how in tune the evaluator was with the hands-on activity. The third question was meant to validate the appropriateness of evaluation tasks selected. The fourth question determined how aligned the evaluator felt with the fictional business established in the Narrative Context. The last question of the section elicited the evaluator's appreciation of the incident scenario's significance relative to the fictional firm. Overall, the section assesses the degree of success of the experience. Capturing an understanding of the level of success of the experience relative to the evaluator was meant to help interpret responses in the following sections.

The second section, "From Your Perspective," was designed to draw out the evaluator's thoughts beyond the limited application of the prototype they experienced. One question sought to elicit what the potential overall value of the IT Incident Visualization System concept might have for the evaluator in the context of their handling responsibilities. The second sought to determine if the evaluator thought a visualization system such as the prototype might be effective in assisting them with decision-making. Instead of simply asking them whether a visualization would be helpful in a broad sense, the question asked the respondent to qualify how the visualization might assist by asking for confirmation of assistance with the following attributes: fact provision, option consideration, impact evaluation across interrelated processes and organizational units, and communicating decisions. The second question is directly related to the research

hypothesis.

The third section, titled "From Your Firm's Perspective," was designed to draw out the evaluator's thoughts beyond their personal benefit considerations. The first question asked if an incident visualization system tailored to their employer might improve IT decision-making processes related to incident handling. If they thought that an improvement was possible, they were asked to rank the magnitude of advantages in terms of awareness, understanding complexity, incident recognition, and understanding impacts. This question provided another evaluative dimension relative to the research hypothesis by exploring the collective aspects of awareness and comprehension of decisions. Three questions sought to ascertain the other dimensions of potential value that visualization could provide. These additional dimensions were reduction of IT incident duration, an objective measure of incident urgency, and overall benefit. Despite the lack of statistical evidence, it is reasonable to believe that, on average, improvements in decision-making would positively correlate to a reduction in IT incident duration. The urgency-related question addressed whether the urgency measure was perceived to be useful for IT incident awareness by professionals beyond those who participated in the field study. Overall, this section provided a rough measure of how aligned the visualization's functionality was to a variety of organizations.

The last section of the questionnaire, "General Wrap-Up," asked respondents for raw feedback about the actual prototype. A large white space was given to accommodate any suggestion that came to mind. The objective of this unconstrained question was to seek out suggestions that would direct future research and development.

5.6.2.5 Purpose of Approach

The Practitioner-Oriented Evaluation Framework was carefully constructed in order to efficiently elicit evaluative feedback on this research in a repeatable manner by carefully managing what the evaluator experienced and the time invested through their

participation. The time budget was by necessity highly constrained, thus requiring that each component of the framework serve its purpose as quickly as possible.

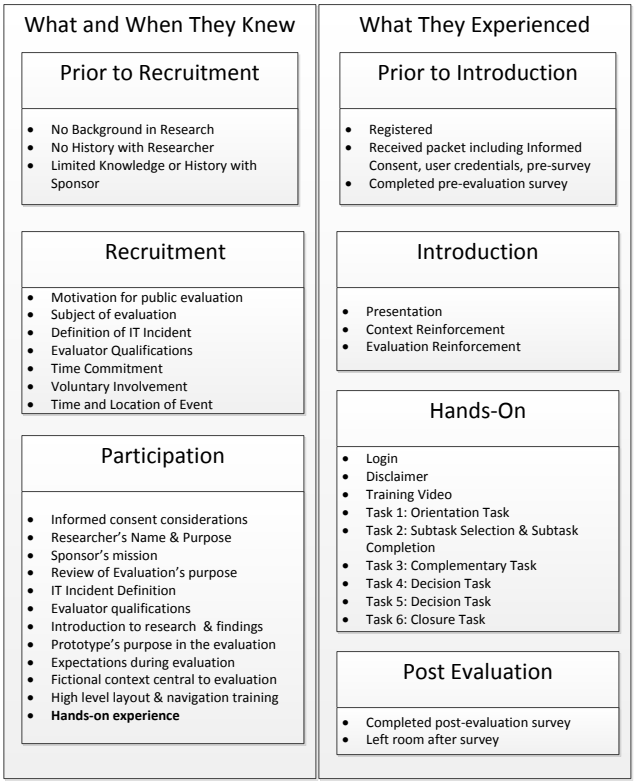


Figure 5.4: Evaluator's Experience

Two figures are presented to show a complementary summary of the Practitioner-Oriented Evaluation Framework. Figure 5.4 is a synopsis of the external stimuli provided by the evaluation environment this section describes, as well as portions described in Chapter 3. Figure 5.5 illustrates the thought progression the framework was designed to facilitate.

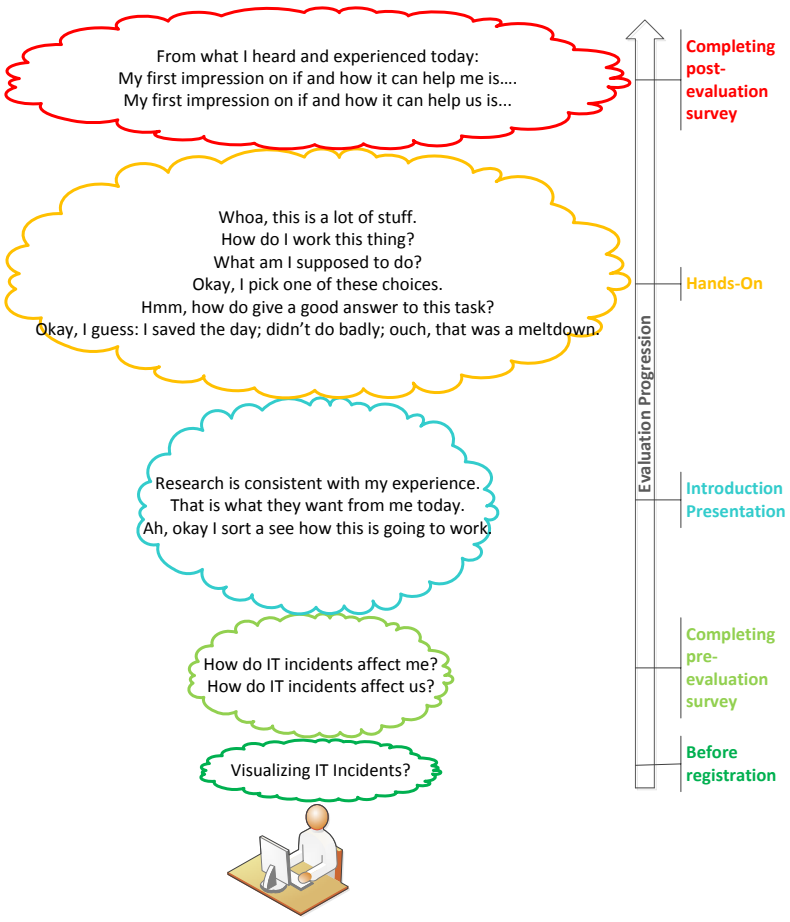


Figure 5.5: Evaluator's Progression of Thinking

5.6.2.6 Evaluation Execution

Although the evaluator's brief excursion into this research had been carefully planned and prepared, there were still relevant details that by comparison may appear to be embellishments. Details were considered to promote consistency between each evaluation, as well as details meant to advance the notion that this work originated beyond the on-site representative, thus encouraging a positive emotional response and sense of role-playing.

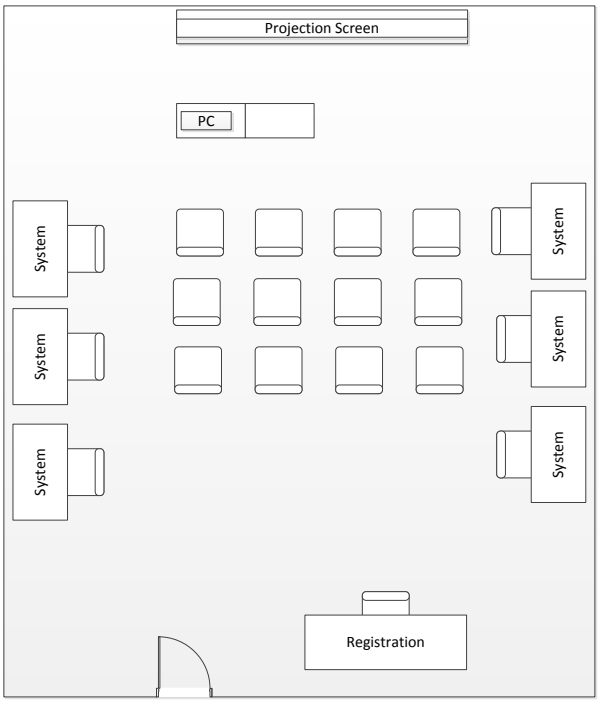


Figure 5.6: Evaluation Room Layout

One significant detail was room layout. The maximum capacity for the evaluation event was six people. There were two primary room layout styles that were implemented based on power outlet availability. One layout style is shown in Figure 5.6; the other was a slight modification in which a pair of system tables was situated behind the center section of chairs, thereby enclosing the center section with pairs of systems. No matter how many evaluators attended, all six systems were available for their use. Participants were encouraged to use the tables for filling out the pre-evaluation survey, and then to move to the center section of chairs for the introductory presentation. Typically, the participant got up briefly to move once again to a workstation for the hands-on portion. Ideally, this brief physical stimulus helped to reset focus. Multiple rows of center chairs in sufficient quantity allowed the six or fewer people to have a choice of where they sat. The shape of the room and placement of the door and projection screen influenced where the registration desk and presenter's table were placed. While the hands-on activity took

place, the on-site researcher sat at the registration desk or any other place out of the way in order to avoid distracting the evaluators.

Comfortable headphones were provided so that each evaluator could listen to the training video. As a personal comfort consideration, disposable headphones-ear-cushion covers and alcohol wipes were offered to ease hygiene concerns. Although these offers may not be of interest to an evaluator, ideally the consideration was appreciated as thoughtful and thorough.

As an added detail to the narrative context being presented in the introductory presentation, a display with a marketing brochure layout had physical examples of the products the fictional company manufactured. The fictional company was loosely modeled after an actual company, which provided samples of products they manufacture. The display was opened up on a stand at the presenter's table. This added touch was meant to reinforce the roles evaluators would be performing in the upcoming hands-on activity.

All of these details and others helped provide inter-event consistency, displayed a sense of competency, and assisted with executing smoothly operating evaluation events.

5.7 Discussion

This section addresses an evaluation design consideration. Other evaluation-based reflections and self-critique can be found in the Discussion section of Chapter 6.

5.7.1 Usability Testing

Although formal usability testing would be a valuable assessment to perform on either this prototype or a future iteration, the evaluation executed in this research did not involve thorough usability testing. Stone et al. mention that usability has five dimensions, namely "Effective," "Efficient," "Engaging," "Error Tolerant," "Easy to

Learn", and that design objectives need not be balanced across these dimensions[83]. This truly was the case in the design of this prototype. Effectiveness and engagement were the dominant dimensions considered during prototype design, and error tolerance was addressed in the evaluation interfaces. The execution of assigned tasks was an attempt for the evaluator to self-assess the prototype's effectiveness. Evaluator interest in both the prototype and evaluation activity can be seen in the amount of time invested in completing each task. Chapter 6 discusses the resulting indicators of both the design's effectiveness and engagement.

There were several impediments to the task of effectively addressing efficiency in the design. The first hindrance was that the Iterative Field Study Methodology did not have another round of Study Group investigations into how the selected evaluation tasks are performed today. The second anticipated challenge was that there is significant task execution variation that results from organizational culture and toolset availability. Lastly, there was the issue of the evaluation itself. Efficiency is a matter not only of how efficiently a system supports the user, but also a matter of how efficiently the user can use the system. In other words, efficiency is in part related to the user's familiarity with the interfaces and tasks. A proper measure of efficiency could not be taken until after minimal mastery of the interfaces and tasks had been established. Accomplishing that level of mastery would have taken more evaluator time, and the effort of developing the necessary training materials would have been significant.

Ease of learning is a challenging dimension of usability to address in the IT incident-handling problem space, which is challenging in its own right. Introducing a tool that facilitates tasks that, possibly, no tools support today raises the potential that any initial exposure to aiding these tasks may pose learning challenges. From a literal execution of evaluation tasks, the evaluator's ability to reach the end of the hands-on activity is a necessary but insufficient indication of whether the environment was easy to learn. Ideally, the IT incident-visualization interface was easy to learn, but no direct attempt

to measure this quality of usability was made. Ease of learning can likely be inferred in any usability challenges evaluators might express in the post-evaluation survey. Optimistically, a designer can hope their initial design succeeds in this category, but ease of learning is one quality that will likely take many iterations to achieve.

Effective error-tolerance evaluation of the IT Incident Visualization System requires that the visualization system be sufficiently functional so that an evaluator can actually use the tool directly to accomplish a task. The medium-fidelity prototype was very tolerant, as user interactions with it had no consequences for the task at hand.

CHAPTER 6. EVALUATION RESULTS

6.1 Introduction

This chapter provides an analysis of the evaluation event data collected from the "Industry Prototype Evaluation." The interpretation and appraisal of these results will also be addressed in this chapter. Given the limitations of the sampling protocol, as well as the resulting sample size, no inferential statistics have been computed. Instead, statistics have been limited to summary measures.

This chapter starts with a section addressing the quantity of evaluation events and challenges related to conducting evaluation events. The next section explores the questionnaire results obtained from these evaluation events. The third section explores the choices and related timing resulting from the evaluators' hands-on activities, while the fourth lays out the criteria used to evaluate the research hypothesis in context with the evaluation data. The fifth section documents the evaluation of the research hypothesis as well as other aspects of the visualization. Finally, the chapter concludes with a brief discussion in the sixth section.

6.2 Evaluation Event Overview

The evaluations took place entirely in central Iowa. Six evaluation sessions were held, but only four were attended by qualified participants. Of the four attended sessions, two were public access and two were held in restricted-access settings. Both of the unproductive sessions were public sessions. One of these was conducted with a single

person who admitted to having no IT incident-handling experience before the event's hands-on activity commenced; the second was simply unattended, and was the first of two sessions that day. An additional four evaluation sessions were coordinated but not held, due to an anticipated lack of attendance. Two additional private sessions received initial support by hosts, but no viable dates were forthcoming. Overall, evaluation events were somewhat difficult both to establish and to populate with qualified attendees.

A total of eighteen people attended the four successful sessions. One of the respondents refused to complete key IT incident-handling experience questions in the pre-evaluation survey, so that person's input was disqualified. The total sample size was therefore seventeen. The reported self-characterization of the attendees is discussed in the "Survey Results" section.

6.3 Survey Results

Survey results are presented in several sections. The first section will review the demographic attributes self-reported in the pre–evaluation survey. The next subsection will analyze the background information previously reported. The following subsection will present the feedback reported in the post–evaluation survey.

6.3.1 Participation Background Data

Among the seventeen participants, five were female and twelve were male. Their median age was 42, and their median IT experience was 15 years. The respondents' median tenure with their current employer was 12.5 years.

Most evaluators had served in various roles across their IT incident-handling history, and all but two had served in a leadership capacity during an IT incident. Twelve of the participants had served in the IT Leader role. Of the five who did not have IT Leader role experience, three had functioned as Incident Coordinators. Table 6.1 provides statistics,

collected over the evaluation events, that describe the backgrounds of the professionals who contributed to the sample. Please refer to Appendix A for the full text of the "Pre–Evaluation Questionnaire."

Table 6.1: Evaluation Participant Background Statistics

Attribute	**Responses**	**Median**	**Mean**	**Std. Dev.**
Age (years)	17	42.0	43.47	7.34
IT Experience (years)	17	15.0	16.41	9.38
Employment Tenure (years)	17	12.5	12.85	4.61
Direct Reports (count)	17	5.0	5.94	5.74
Indirect Influence (count)	15	24.0	6,755.00	25,796.68
Workplace Population (count)	17	800.0	3,266.70	3,680.17
Firm Population (count)	17	14,000.0	18,858.82	12,395.37
Ability to Function (count)	17	15.0	15.41	12.31
Part of Response	17	20.0	119.18	258.09
Workplace Incidents Annually (count)	16	62.5	2,066.75	3,540.75
Cumulative Staff-Hours (count)	7	800.0	902.14	790.90
Costs ($)	6	325,000.0	483,333.33	481,192.96
Min Response Team Size (count)	17	3.0	3.35	2.23
Max Response Team Size (count)	17	25.0	32.29	24.83
Percentage of Outages	16	12.5	36.00	40.51

Nearly all groups (i.e. 16) in which the participants worked were involved directly with information technology. The degree to which the participants' positions were committed to IT incident handling was nearly evenly split, with eight as dedicated responders and

nine called in as the situation dictated.

Some respondents offered a liberal interpretation when asked to describe their organization's purpose. Instead of normalizing responses to question 10 of the pre–evaluation survey, the list of verbatim responses is provided in Table 6.2 in their original form.

Table 6.2: Evaluators' Employers' Businesses or Missions

Business or Mission	**Count**
Education	2
Financial Services	4
Information Technology	1
Insurance	3
Investing, Finance	1
IT delivery for our business partners	1
Productivity	1
Protect the organization	1
Retirement & Investment Services	1
State Government	2

Based on the words chosen, as well as the nature of when and where these participants took part in the evaluation, it can be deduced that two evaluators worked in education, six in financial services, six in insurance and three in state government.

There was an even split among participants with regard to being rewarded for improving IT incident management. Seven believed they were rewarded for making improvements and seven believed they were not; three of the respondents did not know. After reviewing the questionnaires, apparent inconsistencies were seen among participants working for the same firm. This may be a reflection of inconsistent policy and management practices among organizational units.

6.3.2 Participant Background Data Analyses and Considerations

It would appear that the 17 people whose input was solicited and incorporated into this research were qualified. The business sectors represented in this sample were representative of industries dominant in central Iowa. Twelve could be designated as target users who had the IT Leader role experience targeted by the evaluation process; the remaining five were accepted as surrogate users with sufficient experience to emulate the IT Leader role.

The standard deviations of the population questions are large. This was in part due to the diversity of the employers the participants represented. Another consideration in the context of the "Workplace Population" question was the interpretation of the term "workplace." The intention for this response was to limit the response to the population working within the confines of a building. Some respondents chose to associate their response with the organizational unit with which they most directly identified. This insight came from verbal comments as well as from deduction based on evaluation location. Due to respondents' affiliations within larger parent companies, similar underreporting is suspected in the "Firm" population question.

There is a great deal of variance in the "Indirect Influence" question resulting from an outlier of 100,000. It is unclear what this value means, since the person's employer is roughly one-fifth that size. Otherwise, the next largest indirect influence value is 1,000, which is much more reasonable given that the participant's employer is five times larger than that value.

There were a couple of questions on the pre–evaluation survey that posed challenges for the participants. The questions that have a respondent count lower than 17 indicate that some questions were either skipped or the "Don't Know" option was selected. The most cognitively challenging questions were related to approximating the annual costs and staff-hour commitments expended on IT incident handling over twelve months. Beyond the possibility of not having rough operating statistics readily accessible, a con-

ceptually appropriate response should have factored in an IT incident as defined by this research. Participants were asked to keep the definition in mind for all questions related to IT incidents.

A pair of respondents noted that they had 8,000 incidents a year and spent $135 per incident. The product of those two numbers was computed and entered for their responses to the question regarding IT incident costs over twelve months, with a resulting cost of more than $1 million. It is doubtful the responses to the number of IT incidents in the workplace over a year and the cost per incident truly reflected the stated definition of an IT incident. The IT incidents being considered in this research are complex and involve a number of people, and should be relative outliers to the other IT incidents an organization experiences. Nevertheless, taking their input at face value, their employer apparently was experiencing multiple large-scale IT incidents daily.

Beyond those two respondents, maintaining the definition of the IT incident appeared to be an issue for others as well. Three responded that the minimum size of a response team was one, and five responded with a minimum size of two, neither of which was consistent with the stated definition. Eight respondents indicated the minimum response size to be four or more. Overall, the responses to questions related to annual count of workplace incidents, cumulative staff-hour commitments, costs, minimum team size, and percentage of outages were all suspect. These troubling responses provide at best a hazy glimpse into the related aspects of IT incident management.

6.3.3 Post–Evaluation Questionnaire Results

The survey responses are referred to either by their question number or by an abbreviated name. The administered questionnaire can be found in Appendix A.

The questionnaire was designed originally to accommodate an evaluation in which the roles of Business Leader, IT Leader and Incident Coordinator were target users. This question was kept as a “scaffolding” question to help elicit episodic memories of what

the evaluator had just done. Despite the introductory presentation, as well as repeated reminders that the targeted role was the IT Leader, two respondents said that their evaluation role was as Incident Coordinator.

Only ten respondents said that they completed the six evaluation tasks. The question stipulated a timeframe of 20 minutes, and it is believed that some respondents may have responded to be consistent with that stipulation. The 20-minute phrase was another attempt to evoke episodic memory, but it may have backfired given that a majority of the participants needed more than 20 minutes. The next section will address logged activity data in detail, but it is relevant to point out in advance that all but one participant was confirmed as having completed all six evaluation tasks. All but two respondents (i.e. 15) felt the tasks to be reasonable.

Question 4 asked about the similarity in business or mission of the fictional company in relation to the participant's current employer. Although the fictional company was characterized as a manufacturer of composite materials, 8 of 17 participants felt there were "some similarities" between the fictional company and their own firms. It appeared that IT incident and related context were sufficiently common that these eight did not feel that the business sector in which the fictional company was set made any significant difference. Given the diversity of the previously identified business sectors from which the participants came, this response was somewhat unexpected.

Question 5 asked the participant to appraise the overall consequence of the IT incident in relation to the fictional company. For the most part, the expected response was "moderate," and the majority (i.e. nine) said the consequence was indeed "moderate." Four respondents said "low" and the remaining four said "high." Given the potential for the IT incident narrative to adapt to decisions, some variability of response to this question was anticipated. "Moderate" was the assessment expected for even the best-case outcome.

The "jury" of 17 appeared to be mostly (i.e. nine participants) undecided as to

whether a tailored IT Incident Visualization System would help the respondent with their incident-handling duties; of the others, four said "no" and the remaining four said "yes." This curious result is discussed later in the chapter.

Every respondent noted that a visualization system could be effective for supporting at least one aspect of facilitating decisions. Further, everyone agreed that visualization could assist with documenting past and future actions, outcomes and decisions, both during and after the incident. Thirteen said that the visualization could present incident-related facts. Ten said that the visualization could assist with appraising impacts across several interrelated business processes or departments, and nine said the visualization could assist with awareness of options. The most skeptical respondent acknowledged only that the visualization could assist with documentation. Four less doubtful respondents said "yes" to all four listed aspects.

The response to question 8 had multiple steps. If an incident visualization system was anticipated to make no improvement to decision processes, the respondent could simply state "no." But, if the respondent thought that a visualization system would improve IT incident-handling decision processes, they were asked to appraise the advantages they believed the visualization might provide. The appraisal was on a three-position scale, with the lowest value being "very few," "some" as a mid-point, and "many" as the highest value. Five areas of advantage were listed for their appraisal. Three participants said "no" to the initial question and 14 said "yes." The breakdown of reported advantages are listed in Table 6.3.

Question 9 asked evaluators whether an IT Incident Visualization System tailored to their organization would reduce the average time to closure on IT incidents. The participants overwhelmingly (i.e. 13) said that they were "not certain"; only one person said "yes" and three said "no." This result is discussed later in the chapter.

The incident urgency measure identified from the field study effort was put to the test for its general value to the IT incident-handling community. Question 10 asked if having

Table 6.3: Evaluator Assessment of Incident Visualization System's Areas of Advantage

Advantage	**Very Few**	**Some**	**Many**
Incident Awareness	0	6	8
Understanding Complexity	1	9	4
Recognizing Range of Incidents	2	7	5
Understanding Internal Impacts	0	5	9
Understanding Outside Impacts	4	6	4

an objective measure of IT incident urgency similar to what was experienced would help their firm assess the timeliness and adequacy of an IT incident response. The response was that six were "not certain," one said "no" and ten said "yes." Thirty-five percent is a significant portion of the respondent pool to be undecided. This result is discussed later in the chapter.

The last question asked each respondent for a suggestion for improving the current version of the visualization system. Although the question asked for one suggestion, some respondents provided more than one; three participants chose not to respond. For the most part, the suggestions did not provide new insights into aiding IT incident handling at a conceptual level. The suggestions were normalized by way of classification. Four comments were classified as suggestions, three as skeptical observations regarding aspects of the visualization concept, and thirteen were essentially complaints. All but one complaint were related to usability. The predominant usability complaint (five instances) was related to navigation complexity. The next most frequent usability complaint (three instances) was related to interface complexity. Workflow and screen complexity tied for third place, with two instances each. This result is discussed later in the chapter.

6.4 Activity Log Analysis

Although all 17 participants performed the hands-on activity, the reporting that follows had to accommodate two challenges. The first challenge was that the logging originally designed for the evaluation was naïve in expecting that participants could complete the evaluation in 20 minutes. The logging mechanism's time reference was the evaluation timer that counted down from 20 minutes, which failed to log the additional time needed when an evaluator did not complete the evaluation in 20 minutes. This deficiency was addressed midway through the Industry Public Evaluation stage. The consequence was that the time-related data set analyzed does not contain evaluator activity that could not be properly accounted for with respect to time. The second challenge was that a Silverlight crash took place for one evaluator. Due to security concerns related to Silverlight application operations, the activity log could not be written to disk until the very end. Therefore, logging was managed in memory that was lost along with the user's hands-on activity session. As a result, the sample size is 16 or smaller, depending on context.

The activity logs provided insight into the choices evaluators made as well as the timing between choices. The choices were ranked by quality during content development. Efforts were made to reduce the ambiguity between evaluation choices and the content being presented in the visualization. Ultimately, the researcher made a subjective judgment in terms of assessing each choice option. The target of the evaluation was the visualization and not the evaluator. If it had been a simultaneous evaluation of both the user and the visualization, the assessment of each choice option should have been done in consultation with experts in IT incident handling. In his research of chess players, Klein mentions that he utilized experts to rank the quality of chess moves, thereby allowing him to assess decision quality[62].

Despite these limitations in interpreting the significance of the choices made, ana-

lyzing the choices and their timing provides insights on engagement with the hands-on activity and the effectiveness of evaluators in using the visualization.

The choice assessment labels logged and presented here indicate the assessed choice quality by the last character in the label following the nomenclature, *Choice_[X]*. A choice with a last character of "A" (i.e. Choice_A) was best, last character of "B" was acceptable, and last character of "C" was a poor choice. In the last task there were five potential end states for the IT incident narrative, with choices "D" and "E" indicating a progressively worsening outcome. Participants were asked to match values within the reported incident outcome to a list of all possible outcomes. Except for Task 6, the various quality choices were placed in an inconsistent visible order across the tasks. The "worsening" order at the end was deliberate in order for the participant to perform a self-assessment of their performance.

If 17 people simply manipulated the evaluation interface in a random fashion, the expected quantities of particular incident outcomes would be consistent with probability. Table 6.4 shows both the actual distribution of outcomes and a random distribution of outcomes consistent with the state machine design. The table shows only 16 outcomes due to a Silverlight crash. The results reflect three corrections that were made during results analysis. Three users did not select the correct choice that matched the outcome values in the last task.

Table 6.4: Distribution of Outcomes Resulting from Hands-On Activity

Outcome	**Actual Count For Outcome**	**Random Distribution of Outcome**
Choice_A	6	1.778 or between 1 – 2
Choice_B	0	3.556 or between 3 – 4
Choice_C	8	5.333 or between 5 – 6
Choice_D	1	3.556 or between 3 – 4
Choice_E	1	1.778 or between 1 – 2

Another view of engagement can be achieved by looking at the distribution of choices across all of the tasks. Figure 6.2 shows the choices made across the evaluation tasks for those 16 users from whom a log was obtained. As a whole, the evaluator population made an effort to seek out the best choices. Other than for the final outcome of the IT incident, evaluators predominantly selected the best choice. Based on the state machine design, participants who selected the choice graded Choice_C in Task 4 could achieve only the average outcome at best, or Choice_C in Task 6.

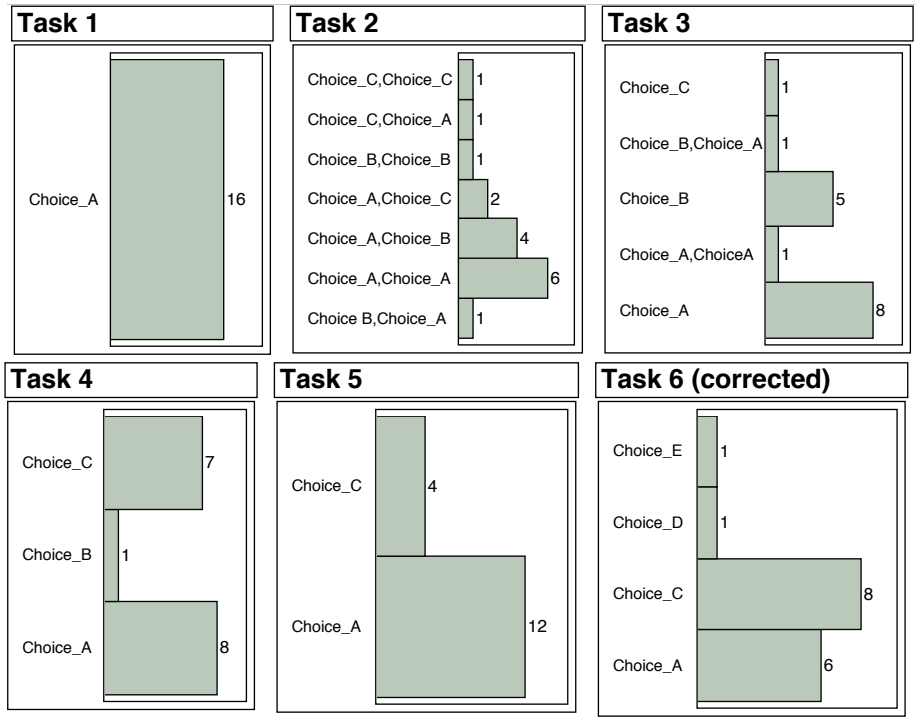


Figure 6.2: Evaluator Choices

In order to decipher the significance of the log entries for Task 2 and Task 3, a brief explanation is needed. Task 2 was designed to require two choices. The first choice was oriented toward selecting an IT incident management task to execute; the second was the choice related to executing that incident-related task. In order to simplify logging, the same decision-labeling scheme was used for the first decision. There was no intended assessment of the task selected, as the labels simply helped to track which task was

selected. The tasks presented were equally valid and valued. The choice made in the second part was assessed a quality value. Task 3 was designed to complement Task 2, in that it presented alternative tasks similar to those offered but not selected in the first part of Task 2. The intention was to expose participants to the same concepts, even though they had the flexibility to pick their activity in Task 2. There were three task states for Task 3, and a user went into one of those states based on the activity selected in Task 2. One of the task states asked the participant to make two choices, which were then recorded in the activity log and assessed a quality value. Appendix M documents the tasks and task choices, as well as providing a mapping of the actual text seen by the evaluator and the assigned label used for logging.

When considering the "choice paths" that evaluators made during the evaluation, there were 15 unique paths or choice patterns, with only one repeat. Given 16 documented choice patterns, diversity was expected. The combinatorics associated with the choice options and state machine yield 360 possible choice patterns. Since choice patterns are conceptually based on judgment and not random selection, some choice pattern clustering should be seen as the evaluation sample size grows. Clustering can, to a minor degree, be seen with the very first task in this limited sample. Since every participant chose Choice_A, there are 54 choice patterns that cannot appear.

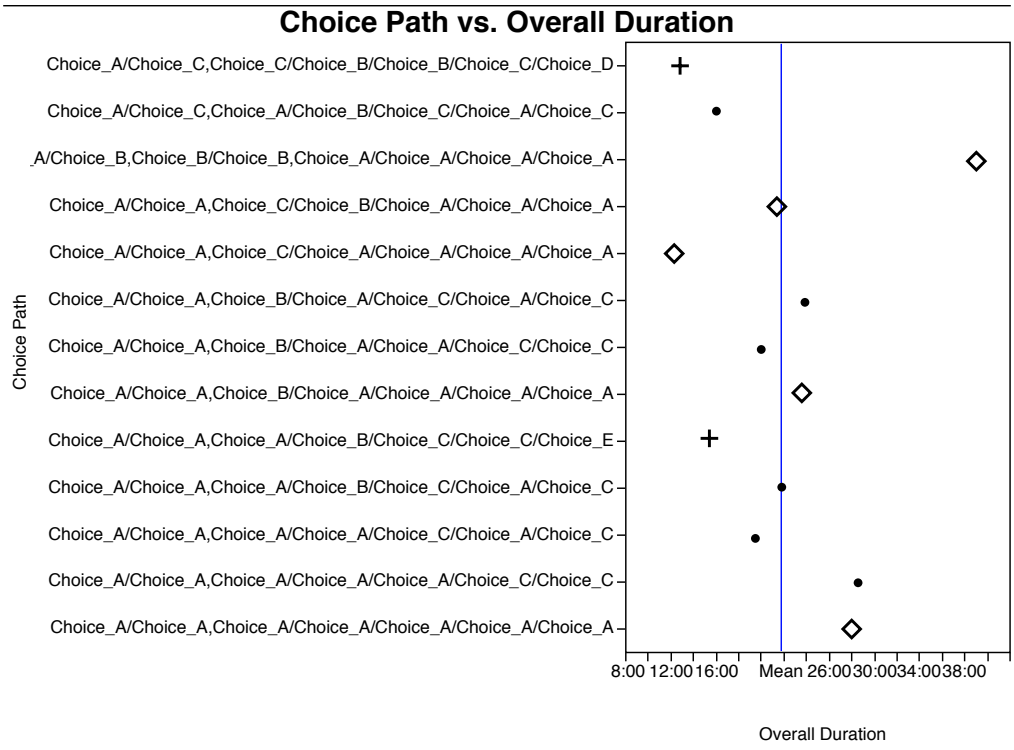


Figure 6.3: Choice Path Durations

The timing analysis on overall duration showed that, on average, it took 21 minutes, 42 seconds to complete the self-paced hands-on activity. Three of the initial participants needed more than 20 minutes as well, but the actual duration of those sessions is unknown. Figure 6.3 shows the respective durations of 13 sessions. The symbols on the plot represent the end state of the IT incident. The diamond represents those sessions that ended with the best outcomes, and the simple points are those sessions that ended with average outcomes. The plus symbol represents sessions that ended below average, but more significant is that these outcomes had the smallest frequency of occurrence. It appears that many of those who achieved the best outcomes were willing to invest extra time in order to make better choices and investigate the visualization screens. The level of engagement appears to have been fairly high. Twelve sessions, including those with incomplete time records, lasted more than 19 minutes.

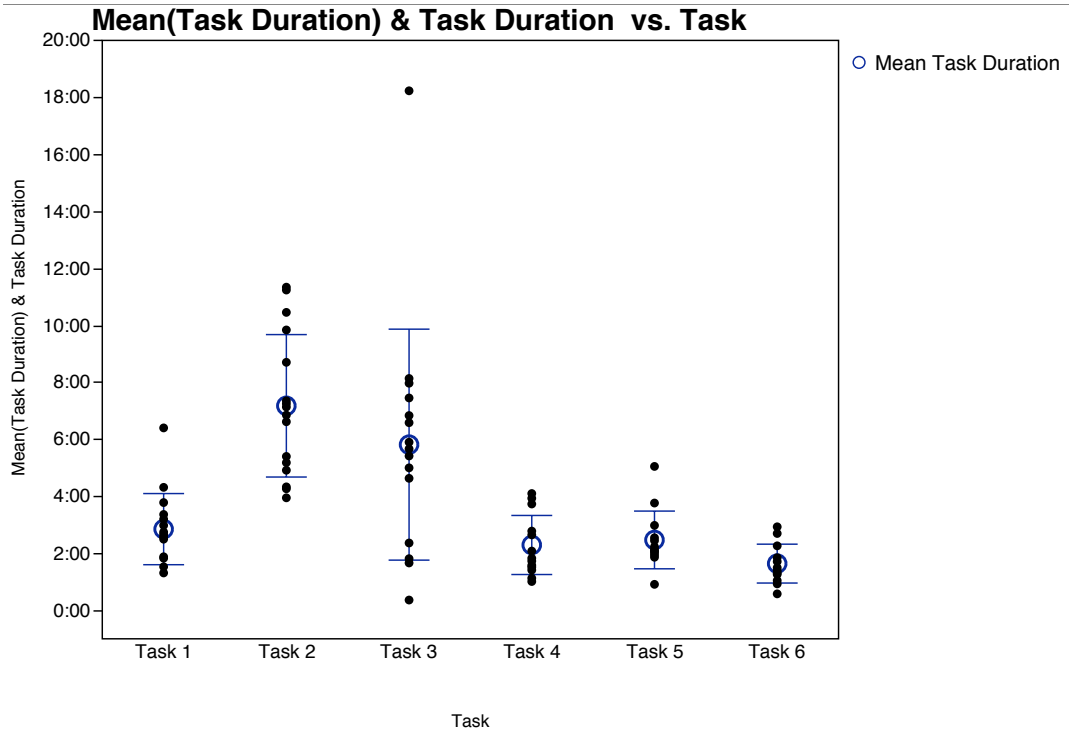


Figure 6.4: Task Durations & Mean Task Duration by Task

By assembling all of the known evaluation task-completion durations by task, one can see the timing patterns associated with the evaluators' progression through the hands-on activity. Figure 6.4 presents the durations by task, with the error bars denoting the standard deviation of duration values. The objective of Task 1's design appears to have been met. As this task was performed fairly quickly for a first task, and the choice quality was uniformly good, the evaluators experienced a quick win. Task 2 took, on average, the longest to perform. This was expected, given the lack of relative structure to the activity as well as the newness of the environment. The remaining tasks were not equal in complexity relative to Task 2, but a reasonably steady decline in task execution took place. Depending on the task state for Task 3, evaluators were asked to watch a video approximately two minutes long that demonstrated a resource request feature they could not effectively utilize with the limited training provided. This video introduced a minimum duration for those evaluators. With a simplistic task execution paradigm

that reduced interaction to selecting several buttons in a confined space and consistent location, one concern was that an evaluator might simply click through to the end. It would appear that concern was warranted for some, as the lowest task-completion times were fairly rapid relative to the mean. On average, however, the evaluation pool appeared intent on using the visualization to make the best choices.

Figure 6.4 shows some very long task-duration times, with one participant who took over 39 minutes. This person was responsible for a number of the outliers such as the one in Task 3. Upon leaving the evaluation, this person offered that she got caught up with exploring, and that it took her nearly to the end to remember to comply with the evaluation objectives. This person was an Incident Coordinator with 25 years of IT experience, and had participated in at least 50 incidents. Not all long durations can be attributed to evaluator curiosity and wandering. Given the reported usability comments, some of these longer durations were likely, in part, the result of human-computer design deficiencies.

6.5 Evaluation Criteria

The criteria presented in this section were used to evaluate the collected evaluation data for the purpose of determining if the research hypothesis had been proved or disproved.

This research did not collect sufficient data with respect to current processes in order to perform a relative evaluation. The evaluation of the visualization was therefore based on its own merits.

The evaluation was limited to the data collected from 17 evaluators. The limited sample size, geographic sampling scope, and business sector sampling scope prevented valid general statistical inferences from being made. Thus, interpretation of the evaluation results was limited to the confines of the sampled pool of professionals.

The research hypothesis stated in Section 1.4 was not directly tested. Instead, the evaluation explored dimensions that address this hypothesis. Those tested aspects of the hypothesis are assembled into composite indicators[82]. Having progressively narrowed the research scope after this hypothesis was established, the scope of the hypothesis was effectively limited to the IT incident management problem domain, with the business leader in this context performing the role of IT Leader.

In order for evaluator input to be incorporated into the hypothesis test process, each evaluator must first meet a standard to establish their input as credible and relevant. There are two acceptable types of users or evaluators. The first type is a user who qualifies as a target user, which is someone with IT Leader experience. The second is a user who qualifies as a surrogate user, which is someone with sufficient experience in IT incident handling, as well as in IT generally, to be able to appreciate the needs and activities of an IT Leader.

More specifically, a valid target user is a person who has stated that they have served in the role of IT Leader, has been part of the response for at least one IT incident over the past five years, and has at least five years of professional IT experience. A valid surrogate user is a person who has stated they have served in any of the following roles: Response Team Member, IT Incident Coordinator, IT Leader, and Business Leader. Additionally, a valid surrogate user will have participated in at least three IT incidents over the past five years, and will have at least five years of professional IT experience.

Another factor to consider is the relevance and reliability of the evaluation framework. There are a number of biases and shortcomings that can be postulated, but many are difficult to measure or observe directly due to the limitations of this research effort. One step related to mitigating sampling biases is to limit the degree of generality of the resulting hypothesis validation to those 17 who participated in the evaluation. A best effort was made to execute the evaluations in a consistent fashion. Beyond the participants, the elements with the greatest variability were the rooms used for the evaluation, the

configuration of furniture and equipment, the introductory presentation, and miscellaneous interactions between the on-site researcher and the participants. The same person executed the evaluation events, but the introductory presentation admittedly varied between evaluation sessions. Although the prototype went through a revision to improve logging, this change was not apparent to the users. Logging was performed entirely in the background, and could be accessed only by a knowledgeable person.

The data collection instruments were printed, self-administered surveys. The greatest reliability risks related to instrument design include the following:

- Based on the target and surrogate user qualifications standards, it was important that participants understood the definition of the IT incident within the scope of this research, and that they were able to count relevant IT incidents in which they participated when responding to question 12. Given the relatively short visual distance to the definition and short delay caused by responding to question 11, it is assumed that the evaluator recalled the appropriate definition of an IT incident and was able to apply this as a filter through their catalog of IT incident-handling experiences.

- The most relevant post-evaluation questions to the hypothesis are numbers 7 and 8. Pre-testing showed these questions to be reasonably designed. Question 8 experienced language simplification and a gestalt-related adjustment between pre-testing and the final version. Question 7 experienced one non-response by one evaluator among the multiple parts. These response parts require a Boolean response, so the absence was treated as "no." Question 8 had one incongruent response in which "no" was selected, but "Advantages" were specified. For the purpose of analysis, this response was treated as "no" and the specified advantages were disregarded.

- Questions 3, 4 and 5 contribute to the assessment of relevance experienced by the evaluator. Questions 3 and 5 tested well during pre-testing, and there were no ap-

parent issues among the 17 respondents. Question 4 was changed after pre-testing in an attempt to narrow the scope of what "similar" meant to the respondent. It appears that some evaluators focused less on the business sector of the fictional company and more on the intention of the environment presented to them. This muddies the interpretive value of the question, but for relevance assessment this outcome is acceptable.

For the reasons stated, the design and execution of the evaluation process are assumed to be reliable within the narrow interpretive scope of the collected data.

Relevance can be measured both directly in the post-evaluation questionnaire and in the level of engagement shown in the activity logs. Given the lack of direct incentive for participating, and with a median age of 42 years and more than 16 years of IT experience on average, these professionals could easily have left prior to completion or simply have clicked through the hands-on activity. Although individuals may have clicked through on some tasks, on average the overall duration was over 21 minutes, or one minute more than anticipated. An additional measure of relevance is directly indicated by the responses to question 3; responses to questions 4 and 5 provide an indirect measure of relevance as well.

Having vetted sources of the evaluation data and established the evaluation protocol as reasonable, composite indicators were constructed based on those inputs. The hypothesis was parsed into two test objectives: one was *improvement of business leaders' decision awareness*; the other was *improvement of business leaders' decision comprehension*. Since this was an absolute evaluation (i.e. no comparison with current processes), improvement could be measured only indirectly through responses to the post-evaluation survey. A composite indicator was needed for both test objectives.

6.5.1 Decision Awareness Evaluation Indicator

An unambiguous composite indicator for the improvement of business leaders' decision awareness was difficult to construct. There are three dimensions to a leader's decision awareness. The first is associated with the initial step toward decision-making of being mindful of an upcoming decision's existence. The second is understanding that the leader is responsible for making the decision. And the third dimension is related to awareness of previous decisions and their outcomes.

An objective review of the "Post-Evaluation Questionnaire" identified few questions that inquired into whether an evaluator noticed that decision awareness took place, or whether they felt it was improved by using the visualization. This could be interpreted as an error in the survey instrument's design. Given the explicit decision prompting in the "Evaluation Task Interface," however, it is not clear that direct questions regarding decision awareness could be interpreted accurately. Without addressing the first dimension of decision awareness, a business leader will not execute a particular decision. Visual elements were presented that related expressly to the need for specific decisions to be made in a timely manner. Decision outcomes and responsibility were presented as well. Evaluators were exposed to the visual elements as part of the evaluation task completion process.

Although it was logically oblique, the composite indicator consisted of inputs from four questions. The most relevant post-evaluation question was 7D, but that question primarily addressed the issue of awareness of past decisions. Because of the visual elements accessed to perform evaluation tasks, questions 6, 9 and 11 indirectly addressed initial decision awareness and responsibility.

As none of the questions in the post-evaluation survey requested a direct numerical value assignment, a convention was instituted in order to compute this indicator. For questions such as numbers 6 and 9, each with three possible responses, a "no" was assigned a -1, a "yes" was assigned a 1, and "not certain" was assigned 0. For question

7, a "no" was assigned a -1 and "yes" was assigned 1. For question 11, the responses were assigned the following: "no benefit" = -1, "minimal benefit" = 0, "good deal of benefit" = 1, "exceptional benefit" = 2.

The indicator was computed simply by treating the responses ($r_{question}$) to the four questions as a summation of values:

$$\sum r_6 + \sum r_{7D} + \sum r_9 + \sum r_{11} \tag{6.1}$$

According to value-assignment conventions, this indicator could range from $-4N$ to $5N$, where N is the evaluator pool size. The 25% value within this range is $-\frac{7N}{4}$, the 50% value is $\frac{N}{2}$, and the 75% value is $\frac{11N}{4}$. Any resulting value between $-4N$ and $-\frac{7N}{4}$ was interpreted as indicating no improvement of decision awareness. If the value was between $-\frac{7N}{4}$ and $\frac{11N}{4}$, the conclusion was that the evaluation of decision awareness was inconclusive. If the value was above $\frac{11N}{4}$, it is reasonable to infer that decision awareness could be improved through visualization.

6.5.2 Decision Comprehension Evaluation Indicator

Having been made aware of a decision, the leader needs to understand the decision. Competency of the leader is a factor in understanding: if the leader does not understand what the decision entails or how to make that type of decision, the visualization is not designed to compensate for this lack of preparation. Assuming the leader is able to make the decision, comprehension in this research hypothesis relates to facilitating sufficient understanding of the relevant variables to commit to a decision outcome. Variables include essential facts regarding the incident's nature, available options, relationships between environmental elements, current incident consequences, and possible incident outcomes.

The post-evaluation survey questions 7 and 8 are the most relevant. Question 7's contribution is limited to parts A, B and C, which are combined to determine whether

question 7 as a whole was a "yes" or a "no." Any one of the attributes associated with A, B and C contribute to comprehension. If any of the responses to A, B and C are "yes," the contribution of question 7 is "yes." But, if none of the responses provided by an evaluator is "yes" to A, B or C, then the contribution of question 7 is "no." Only the primary gate question portion of question 8 is incorporated. Similar to the previous indicator value assignment convention, a "yes" answer is assigned 1 and a "no" answer is assigned -1, as was assigned to contributions provided by questions 7 and 8. The indicator was constructed simply:

$$\sum r_7 + \sum r_8 \tag{6.2}$$

According to the value assignment, the indicator's value could range from $-2N$ to $2N$. N is the value of the first 25%, 0 is the value of the mid-point, and N is the value of 75% in the range. A resulting value between $-2N$ and $-N$ was taken to mean that there was no improvement of decision comprehension. A value between $-N$ and N indicated that the evaluation of decision comprehension was inconclusive. If the value was above N, it is reasonable to infer that decision awareness can be improved through visualization.

6.5.3 Evaluation

The results of computing the "Decision Awareness Evaluation Indicator" may be seen in Table 6.5. The total was 28. The 75% value was 46.75. The conclusion is that evaluation was inconclusive regarding the improvement of decision awareness.

Table 6.5: Computation of the Decision Awareness Evaluation Indicator

Question	**Contribution Value**
6	4(-1) + 4(1) + 9(0) = 0
7D	17(1) = 17
9	3(-1) + 1(1) + 13(0) = -2
11	0(-1) + 4(0) + 13(1) + 0(2) = 13

The results of computing the "Decision Comprehension Evaluation Indicator" may be seen in Table 6.6. The total was 26. The 75% value was 17. The conclusion is that, for those who participated, the evaluation determined that decision comprehension did improve by using a dynamic visual system.

Table 6.6: Computation of the Decision Comprehension Evaluation Indicator

Question	**Contribution Value**
7	1 No and 16 Yes thus contributing 15
8	3 No and 14 Yes thus contributing 11

In summary, the evaluation proved the decision comprehension aspect of the research hypothesis, while remaining inconclusive regarding decision awareness in the context of 17 evaluators. Hence, further research is needed both to justify the general applicability of these results as well as to replace the inconclusive outcome with a more conclusive determination as to whether decision awareness can be improved through visualization.

6.6 Discussion

This section provides brief reflections on evaluation results as well as a self-critique of their reliability.

6.6.1 Operational Glitches

Three of the 17 evaluators experienced operational issues. One issue, previously discussed, was that a Silverlight crash took place while the evaluator was either completing Task 5 or 6, per the participant's recollection. Further investigation into the incident could not reliably reproduce the problem, so the cause could not be determined.

Two other issues were operationally related, but more from an operator perspective. Strangely, the two instances were the same issue occurring in the same evaluation session by two evaluators on the same side of the room. Since the on-site researcher stayed away from the participants while they performed their hands-on activity, it is not clear what actually happened. After performing post-session testing, the only plausible explanation for the issue was, fundamentally, a usability or operator attentiveness error. As previously mentioned, Task 3 compensated for the task choice made in the first part of Task 2. Two of the compensatory states of Task 3 involved a video that provided an example of how a resource request could be made. The two evaluators failed to see a large (139-pixel wide x 99-pixel high, or 0.87% of all screen space) light-gray-to-red horizontal gradient-filled button with a black text label that read "Close Video Player" within the prototype portion of the user interface. Among the eight buttons within the entire screen space, this was the largest button visible on the interface in terms of surface area. The next-largest visible button was 139 pixels wide x 33 pixels high. Next to the "Close" button was a button aligned on center to the right, 9 pixels away, labelled "Go back 15sec." To the right of that button was a button labeled "Pause."

For whatever reasons, these two participants failed to close the player and proceeded to complete the tasks, despite not being able to see the relevant prototype screens. This was mechanically feasible, since actions necessary for task completion took place in the right-most portion of the Evaluation Task Description region of the screen. The problem became apparent to the on-site researcher at the end, when one of the two participants suggested that there may have been a user error or software glitch that caused the video

player to be visible at the end of the evaluation. Naturally, their choices for Tasks 4, 5 and 6 were mere guesses. When reviewing Figure 6.3, one can identify these participants' choice paths by their brevity (12:16 and 12:46 in duration). The second participant left the session with the video player still visible and made no comment when handing in the post-evaluation survey. Both participants' Task 6 choices had to be corrected in post-analysis to match what was actually feasible according to the state machine. One participant was female and the other male. Red-green color blindness may have been a partial explanation for this problem. As one can imagine, their experiences negatively affected their post-evaluation input. With such a small sampling, it is hard to determine if these two cases were a result of some odd situational abnormality or this was truly a symptom of a fairly serious usability issue.

6.6.2 Interesting Survey Responses

6.6.2.1 Question 6

As mentioned previously, among the accumulated responses to question 6, nine evaluators could not decide whether a tailored IT Incident Visualization System would help them with their incident-handling duties. What makes this an odd outcome is the result of question 7, in which all evaluators indicated some value being added to decision-making. It would seem reasonable to assume, therefore, that if they perceived decision support was being improved, they would consider that to be helpful. If the question order had been switched, would there have been a coupling effect that would have changed the aggregate result to question 6?

This degree of uncertainty raises alignment questions regarding the evaluation. The undecided participants clearly did not get the experiential information needed to decide. This indecision is motivation for reviewing and adjusting the evaluation experience so that respondents can make a decision with regard to this important question.

6.6.2.2 Question 9

Reducing the time to incident closure is an important objective. If an IT incident cannot be prevented, then efficient and effective closure is the next practical objective. Once again, exposure to the visualization provided by the evaluation environment was not sufficient to allow evaluators to decide this question. This indecision could be based, in part, on the enormous diversity of possible IT incidents in practice, whereas experiencing only one in a fairly rigid context might not provide sufficient experiential data for evaluators to extrapolate to a broader context. Despite multiple exposures to the definition of which IT incidents were relevant to this visualization, it is very possible that some evaluators truly did not integrate the appropriate definition into their thinking, and therefore could not see how this visualization might be relevant to the much lower-profile incidents. The definition was not repeated in the Post-Evaluation Questionnaire.

The usability issues many experienced with the visualization may have contributed to their doubt. After more training and improvements in usability, future evaluators may be able to make a definitive decision. Usability is a design and development issue, and training issues reflect back on the evaluation design. Both of these are practical short-term objectives for future research.

6.6.2.3 Question 10

Having 10 of 17 evaluators acknowledge the importance of having an objective measure of IT incident urgency is a welcome outcome, and in a small way validates the field study. A formal effort is needed to construct a reliable and respected measure of IT incident urgency.

The uncertainty of six evaluators is noteworthy. More research is needed to address this uncertainty. This uncertainty may have resulted from the lack of a formal presentation of the measure's derivation or by not providing an accessible explanation of the significance of the measure's values and/or the absence of an explanation of its limitation

as a vital IT incident indicator. The evaluation experience's short duration, as well as its single IT incident, may also have been factors. Experiencing multiple IT incidents during which urgency is consistently computed and referenced may also improve evaluator appreciation of its significance or lack thereof.

6.6.3 Biases

6.6.3.1 Social Acceptability [88] or Social Desirability Bias [89]

Social acceptability or social desirability bias relates to respondents reporting what they suppose the questioner wants to hear. It also relates to unwillingness to report (i.e. underreport) things that may shame or discredit themselves. The article regarding social desirability bias also points out that respondents will exaggerate their responses (i.e. overreport) when doing so will present themselves in a positive light[89]. The first aspect of this bias was of greatest concern with regard to evaluation feedback. Overreporting and underreporting could have been factors in responses to IT incident history provided in the pre-evaluation survey. Several mitigation steps were taken to minimize the impact of this bias. The evaluation protocol was explicitly to collect data anonymously, so that the respondent should not have felt exposed beyond those moments filling out the survey and handing it to the on-site researcher. The self-administration of a paper-based survey should have avoided the embarrassment or stigma that might occur in an interview-based survey. Beyond that, deliberate efforts were made to avoid the first aspect of this bias as a result of any perception that the on-site researcher was directly affiliated with the research. The size of the research team was projected to be greater than a single individual. Using the Information Assurance Center director's name in calls for participation achieved this end, as did the professionalism of the surveys' design and production, video production quality and use of another voice, pervasive branding using the Information Assurance Center's logo, and the quality of the software developed. Materials that referred to the on-site researcher made it appear that the

researcher's job was to conduct outreach activities. This particular evaluation was, by implication, simply an assignment undertaken by the on-site researcher. By constructing the perception that there was a remote group of researchers responsible for the research, it was easier to suggest that the on-site researcher was not necessarily associated with efforts leading up to the evaluation.

6.6.3.2 Self-Selection[90] or Voluntary Response Bias

This bias has two significant forms in this research. First, although the call for participation described the desired qualifications, unqualified people could have attended by knowingly disregarding or loosely interpreting the qualifications. Because such an unqualified participant would not be a member of the target population, this could result in a bias. Some of the fault for this can be placed on the stated qualifications that were intentionally imprecise so as not to alienate qualified participants with highly detailed descriptions or overly complex recruitment specifications. Ultimately, with no viable means to encourage participation while at the same time screening prospective attendee qualifications, vetting could be done only after participation had concluded. And while the pre-evaluation survey asked participants to report on their IT incident background, thus revealing their qualifications, this attempt at mitigation could have been thwarted by self-reporting bias.

The second form of this bias was inherent to the recruitment mechanism being a voluntary response: only those with the time, flexibility and interest participated. In the private evaluation settings, it was believed that an employee of some organizational stature invited individuals to consider participating voluntarily, and that these invitees could decline without repercussion. Beyond the supportive nature of encouraging participation, it was unclear what cultural or relationship pressure the individuals might have felt to participate. Assuming that in all cases prospective participants did not feel unduly compelled, their voluntary presence introduced the risk of biasing the collected

data. Those who volunteered may not have been, in the aggregate, representative of the target population. This bias is a consideration when evaluating the collected results.

6.6.3.3 Self-Reporting Bias

There are two dimensions to this bias. Although not designated as a bias within the article on self-reported measures within "Encyclopedia of Survey Research Methods", the article mentions that self-reported measures assume the respondents are able and willing to provide accurate answers[91]. The second dimension of this bias overlaps with the social desirability bias with respect to respondents overreporting when doing so will reflect well on them[92]. Anonymity may help alleviate this effect, but Donaldson et al. suggest that a respondent may not be convinced that their response is truly unattributable. This bias needs to be considered when evaluating the professional history information provided in the pre-evaluation survey.

6.6.3.4 Non-Random Sampling Bias

Random sampling is an ideal means for collecting feedback, but, realistically, a rough approximation was the best that could be achieved. There are several reasons for this shortcoming. Access to independent professionals was restricted, as a comprehensive listing of IT professionals available for random sampling does not exist. Furthermore, interest in the topic was essential for a participant to make the time necessary. An additional practical constraint was a prospective evaluator had to have work flexibility or permission to participate.

The geographic scope of recruitment was limited due to logistical as well as relationship constraints. With constant demands on an IT professional's time, motivation beyond casual curiosity was needed. This is consistent with Treu's observation regarding recruiting prospective users[82]. Direct incentives were not provided to avoid the incentive becoming the primary objective. Additionally, IT professionals are fairly well

paid, so no reasonable financial incentive would sufficiently compensate them for their time. Altruism is a worthy motivation for volunteering, but schedule impediments and priorities commonly overshadow altruistic impulses during the workday. Therefore, local encouragement by coworkers and managers was typically required. Commonly, this encouragement originated from people with relationships or experience with the researchers, sponsoring organization or its parent (i.e. Iowa State University). Relationships with the researchers were a bias of great concern for those who actually evaluated, but were less troubling when limited to those simply encouraging others to participate.

As physical convenience was a key factor for nearly all who participated, cluster-sampling bias was necessarily introduced as a consideration. The most populated evaluation events took place in a conference room located within walking distance of participants' work areas, a factor that influenced host selection. Hosts who were willing to facilitate an evaluation among their employees were pursued. Four key factors appeared to influence their consent: 1) relationships, 2) size of IT organization, 3) location of IT organization, and 4) availability of a coordinating employee to facilitate preparations. Large companies with facilities nationwide may have a regional presence, but their IT organizations can be located in any state.

6.6.4 Influence of Evaluation Tasks

The evaluation tasks strongly influenced the goals evaluators used for the visualization. Their success in achieving these goals was likely reflected in their evaluation feedback. The conclusions drawn from their feedback are constrained in part by the evaluation tasks they were asked to perform. In other words, if another set of role-relevant tasks had been developed, there could have been a different evaluation outcome. A broader set of role-relevant tasks would need to be developed, as well as implementation of a carefully designed experiment that assigned tasks in such a way as to minimize the effects of evaluation tasks on evaluation interpretation.

CHAPTER 7. OBSERVATIONS AND DISCUSSION

7.1 Introduction

This chapter is dedicated to observations and discussion to bring closure to the work done to date. Some of the discussion spans the various facets of this research, providing an overarching self-assessment and interpretation of what has been accomplished.

The next section, "Research Significance," puts the contributions of this research into context. The following section, "Solution Challenges," discusses concerns regarding the viability of solutions raised by professionals over the course of the research. "Project Design," which follows, discusses challenges in the design of the research effort. Many lessons were learned over the course of this research, and some of these are discussed in "Lessons Learned." Some noteworthy observations are made in "Reflections". The final section, "Summation," brings the discussion of the entire project to this point to a close.

7.2 Research Significance

Business impact visualization is a real and vital sub-category of security visualization. The presented catalog of needs illustrates the breadth of challenges being faced. With more focus and time, the catalog could surely be expanded. At the heart of these challenges is problem visualization. The amount of conceptual scaffolding needed by leaders is increasing as technologies, solutions and their business significance increase in nuance and complexity. It does not appear that many leaders either want or can afford to be "backseat technologists." For these people technology is merely a means to an end,

and business leaders appear to need and desire tools that can simply frame technical security and compliance issues and concerns in relation to their obligations.

IT incident management is costly and prevention imperfect. The breadth of security visualization literature shows the intense effort invested in developing tools to search for and verify the existence of "needles" of malicious activity in the environmental "haystack." Nearly all Study Group members would agree that routine operational IT incidents overwhelm the number of incidents that are verifiably actionable in terms of integrity and/or confidentiality. Time equals not just money but opportunity costs as well: business processes affected by an incident are not adding their expected value, and staffers reassigned to resolve the incident are not doing work that moves the business forward.

Timely engagement, awareness and comprehension are challenges today. Improvement of a business's ability to respond effectively and efficiently to even the most complex IT incidents is needed, and business leaders are an integral part of that response. Their indecision or inaction, not to mention poor decision-making, can increase business risk and drive up costs related to response. The IT Incident Visualization System developed for this research was reasonably successful in improving decision comprehension. However, more research is needed to confirm that decision *awareness* can indeed be improved. It is logical to believe that any improvement in decision awareness can be confirmed, and that awareness precedes comprehension. So if comprehension can be improved, then it only follows that business leader awareness can be improved as well.

User-centered design is steadily being adopted within the security visualization research community. The voice of the customer needs to be trusted, but then verified as well. Although many users are not skilled in the various disciplines within visualization design or software development, they know their problems and can articulate many of their needs. In this regard, solution developers are the learners and users are the teachers. As with any form of education, assessment of understanding is needed, with the

"final grade" based upon successful adoption and use. Borrowing from constructivist education theory, it is better to identify and correct a misunderstanding earlier rather than later in the learning process after significant investment has already been made.

The iterative methodology undertaken in this research sought to enrich and verify understanding of users and their needs in steps taken progressively toward a completed prototype. Admittedly, the approach taken may have been relatively unorthodox in allowing the Study Group effectively to choose the problem space and directly influence and prioritize requirements. Another unique element of this methodology was its reliance upon a stable set of professionals (i.e. Study Group). Although the group's membership was fairly diverse with regard to employer's business sector, job position, professional background and company size, consensus on the problem space reflected the common challenges organizations have with IT incident management. Understanding the limitations of utilizing a stable group of user-consultants, this methodology set out the challenge of independent evaluation from the outset.

Requirements review and prioritization by the user was essential. There is considerable interpretation and blending of requirements during development. The user would be hard-pressed to isolate a requirement on which to provide feedback when assessing an implementation. The designer might be equally challenged to match collected feedback to a specific requirement. Given how humans learn and perceive, N group members' and M researchers' readings of a requirement are likely to result in $N + M$ unique understandings. Shared context, concise writing and discussion will, ideally, corral and align these understandings around the intended understanding with minimal dispersion. Statistically, the Study Group was probably too small in general, but more specifically, breakout by role arguably diluted the limited statistical reliability the group could provide. If, however, the group members were not instructed to apply a specific leader role, it is reasonable to assume they would still draw from their personal experience in the workplace, thus implicitly applying a role-oriented lens. Future efforts might determine if

those who work for other business sectors in different regions agree with the prioritization performed.

The evaluation framework consisted of many parts. The overall evaluation event design was consistent with other evaluation protocols within the security visualization research area. The underlying "Choose Your Own Adventure"-styled evaluation encouraged engagement while limiting development complexity. A single path through the evaluation would have been much simpler to develop, but that would have been essentially a self-controlled demonstration, and therefore not as appealing to the evaluators for engaging and considering the various concepts' potential. The software interfaces developed for the evaluation facilitated multiple independent evaluations in one session, a circumstance that is not conducive for evaluations seeking a detailed understanding of either usability challenges or the participants' thinking. Conducting multiple independent evaluations, however, is a complementary form of testing that allows for statistical analysis and is efficient with respect to researcher effort.

Survey and human-computer interface testing have much in common. Dillman and Redline discuss the value of field experiments and cognitive interviews for testing self-administered, paper-based surveys[37], observing that field experiments allow one to determine whether a design feature's influence on response rates or data quality is statistically significant. The downside of field experiments, they note, is that they do not provide an explanation for this change. They suggest that cognitive interviews in the form of "think-aloud" protocols or retrospective methods are a means to explain the difference. Much of the evaluation performed by security visualization researchers has been aligned to cognitive interviewing as opposed to field experiments. Field experiments are needed to acquire a more generalizable understanding of the usefulness of visualization techniques. The evaluation framework developed for this research contributes to the body of possible approaches for conducting repeatable and reliable field experiments. The "master-slave" relationship implemented between the prototype and evaluation in-

terface, as well as the forced-choice response formats, were artifacts of the desired level of prototype fidelity. These constraints can be lifted if a high-fidelity prototype is available.

Information security has very few absolutes in practice. Risk avoidance is impractical for most organizations, which typically are designed to assume risk. Risk profiles conform to dimensions that include an organization's business sector, goals, values, personnel, locations, reputation, practices and an immense number of technological variables. Having developed a fictional entity for the evaluation allowed for merely a shadow of these dimensions to provide relief or context to the decisions evaluators were asked to make. Going forward, coherent organizational constructs are needed for testing the effectiveness of security visualization solutions, as the technology attributes of a security decision are only one dimension of business-sensitive decision-making.

7.3 Solution Challenges

Over the course of the field study, the Study Group raised a number of likely impediments that will need to be addressed for the IT Incident Visualization System to succeed in practice. Those mentioned were the most significant issues raised or inspired by the group's observations.

7.3.1 Security

A reliable solution for assisting with complex and possibly large IT incidents needs to be resilient. In the context of a malicious IT incident, such a tool could provide an attacker or intruder a means for injecting false information, as well as the ability to obtain a considerable amount of useful time-sensitive intelligence. These considerations should be incorporated as solutions transition from concepts to functional products.

"Need to know" is a security principle that must be embraced in the visualization's design. But, "need to know" is not time- or situation-invariant. Sensitive environmental

design or operational information that, during normal operations, is intentionally or inadvertently compartmentalized may need to be shared in order to establish sufficient context for critical time-sensitive decisions. Implemented controls on information access should allow authorized users to temporarily relax "need to know" on an IT incident-sensitive basis.

7.3.2 Integration

There are a number of challenges to implementing a solution today. An effective IT visualization will, logically, encapsulate a variety of monitoring, resource management and workflow systems. This will require extensive services-integration design and implementation. In addition to integrating these systems, new analytic capabilities are needed to compute IT incident urgency; calculate direct-cost risk; estimate response risk; model imminent operational/security/compliance impact; assess uncertainty; perform incident-extent tracking; and assist with computing short-term security, compliance and brand risk. Currently, comprehensive portfolio management that tracks and maps business processes to relevant supporting elements (e.g. systems, personnel, data sets) is nearly non-existent. It is therefore safe to assume that an IT Incident Visualization System will not be practical for a while.

7.3.3 Personnel Overload

Operational awareness has its costs, one being the burden placed on those executing response tasks to keep visualization users apprised of their progress and relevant outcomes. Mobile interfaces are essential for these people. Where possible, their reporting burden should be lightened through interface usability and transparency. The goal of transparency would be to achieve information-gathering objectives without requiring the responder to remove focus from the tasks at hand. This likely will be manifested in eavesdropping, interactivity capture, and other techniques that will need to be aligned

with privacy and professional jeopardy concerns.

7.4 Project Design

The particular means by which this research was conducted introduced idiosyncrasies that have likely influenced the outcomes. This section explores some of those peculiarities.

7.4.1 Repeated Involvement

As mentioned in the literature review within Chapter 2, in many cases user-centered design has not involved the same users consistently throughout the design cycle. While user availability and burden are reasonable considerations, another may be the need to seek fresh ideas or perspectives. One challenge the researchers cited in the review do not discuss is the penalty arising from a lack of continuity. Involving the same users allows the designer and user representatives to establish rapport, build common ground on ideas, confirm understanding of past conversations, and build an evolving common understanding of the design objectives. But unless a research sponsor makes many user representatives available, accessing additional members of the user community can be difficult. How much more general of an understanding can be achieved by seeking out another nine or ten people? This question is more meaningful if the additional people come from the same organization or organizations with similar operating models (e.g. federal agencies and their contractors).

"Trust but verify" was an essential user-centered design philosophy adopted by this research. Having repeatedly engaged the same user representatives to reach a milestone, it was important to seek out independent assessment. Not only is this good research methodology, it is also potentially a means to recruit others for future work.

7.4.2 Bias

Chapter 6 identifies a number of sources of bias that should be considered when interpreting results. One bias not listed, but clearly relevant, is researcher bias. With only one researcher performing data collection, design, analysis and interpretation, the researcher has great influence on the outcome. But while self-assessing researcher bias in this situation is not likely to be successful, it is nonetheless reasonable to believe that it is possible.

There is, however, some advantage in having a single researcher perform the field study interviews and independent evaluation. First, it is challenging to account for the variance introduced by inconsistency among interviewers or evaluation facilitators. Multiple researchers present at user-centered activities certainly might improve data quality. But to achieve a similar variance-avoidance benefit, the same team would need to execute all instances of the same user-centered activity, performing their duties consistently.

External sources of bias are assumed to have had minimal effect on the validity of the narrowly scoped claims of this research that 1) a population of 17 independent professionals acknowledged improvement of decision comprehension, and 2) this same group of 17 was undecided regarding improvements in decision awareness. The most significant sources of bias would have been a lack of independence and objectivity. While great effort was made to ensure independence of the evaluators from the researcher, the influence of the Information Assurance Center and its director on any of the evaluators' judgement cannot be known. In spite of this, this effect is unlikely to have been significant. Ultimately, additional hypothesis testing by other researchers will, in time, either refute or support these claims.

7.5 Lessons Learned

Beyond the minimal experience obtained previously in a course project setting, this is the first user-centered design effort of this magnitude undertaken by the researcher. The industrial experiences of the researcher were helpful, but ultimately much was learned from this initial foray into such an intensively human design effort. Some of the more significant lessons learned are shared in this section.

7.5.1 Further Task Analysis and Usability Testing

The objectives for "Stage T. Review Visualization Prototype" (Section 3.2.18) were a bit misguided. This stage was designed to emulate the independent evaluation by being a "true" test run, in that group members would be dropped into a situation for which they had little previous familiarity with the prototype or tasks to be performed. Their lack of independence from the research made their responses to yet-to-be-finalized survey instruments moot in terms of the final analysis, thus making evaluation emulation less compelling and, more importantly, losing an opportunity to address usability and perform task analysis. Executing Stage T did result in improvements in time for Stage V, but potentially significant usability issues could not be addressed in the intervening period.

Stage T should have been broken down into additional stages. A test run of the independent evaluation process was absolutely essential. Nevertheless, a number of fundamental assumptions regarding task performance were made over the year of prototype development. Stage H (Section 3.2.7) uncovered a great deal about the IT incident management problem space. The tactical activities developed to be evaluation tasks, however, were not explored from an execution perspective: the project started by looking at the forest (business impact visualization), selected and examined a pine tree (IT incident management), but failed to inspect a number of pine cones (evaluation tasks).

A revision of the methodology would include two additional user-centered activities and a repurposed Stage T. After selecting the evaluation tasks and undertaking some initial implementation, an "Evaluation Task Analysis" stage would be added in order to walk through how Study Group members might perform the assigned tasks, with the results informing additional development. Having nearly completed prototype development, the researcher would then return for usability testing with regard to the evaluation tasks. Further development refinements could result from this second additional stage. Instead of attempting to combine usability feedback collection with an evaluation event test run, Stage T would be strictly an evaluation event dry run and survey instrument pre-test.

Without additional resources, these changes to the methodology would likely have added an additional six to nine months. The possible benefit of this approach would be to overcome initial usability pitfalls the independent evaluators might encounter. Poor usability may have been the one obstacle that kept many from providing definitive answers to key post-evaluation survey questions.

7.5.2 Study Group Composition

When building the group, a diverse collection of experienced professionals was sought. But no matter what level of diversity could be achieved, there was always more diversity possible. Although organizations have much in common in terms of security and compliance objectives, their differing cultures, budgets and risk management objectives strongly influence actual practice. Management of high-value IT incidents has yet to be "normalized" by introducing widely recognized and adopted tooling. As flexible as enterprise software such as BMC Remedy or SAP business management may be, they introduce constraints that limit business process variance among those implementing them. The semi-manual process of IT incident handling is diverse in execution between organizations and among incidents as well. An attempt to identify all of the variations in

approach would have been incredibly labor-intensive, and likely would have overwhelmed any effort to provide visualization support.

The number and variety of people available for recruitment into the Study Group is a function of outreach. Enlisting volunteers requires that they be made aware of the opportunity, in addition to being available and having the appropriate background. With a research team of effectively just one person, there was a practical limit as to how many group members could be effectively utilized. This was not simply a matter of coordinating and conducting sessions with each member, but also of post-processing and analysis. Seven was a reasonably manageable number. The diversity among them was good but could have been better, and an additional leader with a business management perspective would have been especially helpful. Although somewhat of a contradiction exists in recruiting a business manager for a long-running investigation into technology, as a person who has chosen a business career might not be sufficiently interested in technology research to devote 15 hours over multiple years.

Research involving volunteers is stochastic by nature, and another sampling of volunteers might have yielded different insights. Many of the core findings from this research should hold after further investigation, but greater nuance related to roles and task performance is likely to be introduced. For example, the IT Leader has effectively been defined as fulfilling a "bridge" function between Business Leaders and the technical responders, such as the Incident Coordinator and Response Team Members. As such, in some organizations this role is effectively a substitute for the Incident or Event Coordinator, while in others response coordination is not a duty of the IT Leader. Furthermore, in some organizations the person assigned the role of Incident Coordinator may not at the same time perform task assignment. This may be a matter of role-definition misalignment, because whoever is performing task assignment is effectively coordinating the response to the incident.

If an IT Incident Visualization System were to be implemented with the current

understanding of the various roles, the result would be a "normalization" among those not using the same role names or definitions. The organization would need either to adapt its current conventions to the tool or try to realign the built-in roles to their culture. Ultimately, a little of both would likely occur. Ideally, the result would improve the organization's handling processes as well as align them to some objective measure of best practices.

7.6 Reflections

Having invested three years into this effort, as well as considering the significance of evaluation results, a number of observations can be made. The observations in this section are some of the more intriguing insights.

7.6.1 Study Group Member Personality

Besides professional experience, age, employer and interests, personality is another important aspect to consider for those providing guidance over a broad span of the development cycle. "Personality" in this case should be considered in terms of thinking styles. There are those quite comfortable with abstract thinking, on the one hand, and those who speak to more tangible interests, values and concerns on the other. There are those who can identify and articulate generalized challenges and make relevant suggestions, and those who must see a logical sequence leading to a concept before considering that concept. Yet while there may be many who are willing to take a leap of faith and consider the concept on its own merits, their faith is not the same as blind trust. If the concept has merit, these people will need the logical sequence articulated prior to acceptance. In any event, each participant engages in his or her own way, thus making consistency of execution challenging.

Building a long-term study group is an investment. Objective criteria such as age, experiences, availability and current job are likely filters used for group member selection. Given that participation is voluntary, a person's thinking style is initially a secondary criterion. Ultimately, the assembled group populates a portfolio of thinking styles. Unless you attempt to a build a group having a "monoculture" in thinking style, one can expect a diversity of thoughtful responses to the same questions, not simply in fact (e.g. the average duration of an incident) but regarding the nature of the thought itself. This challenge is difficult to articulate. Still, a crude analogy might be that, if multiple people were asked the same open-ended question, one could elicit a philosophical response, a strictly factual response much like ideal witness testimony, a response with imagery and analogy or, possibly, an anecdotal response. There is value in all such responses, but it is a challenge to normalize on such a basis. Indirectly, these assembled responses might imply confirmation with another source, but that could simply be interpretive bias. Forcing normalized approaches to responses would make coding easier for a formal qualitative study, but approaches to thinking are highly individualistic. Seeking normalized response approaches may make some uneasy and may also jeopardize creative and abstract thinking. Furthermore, tacit knowledge needs to be drawn out, which requires triggering memory that may be accessible only by allowing other thoughts to be retrieved first. When using a stable group for user-centered research, one should consider the assembled portfolio of thinking styles.

7.6.2 IT Incident Impact & Improvement

It appears that practitioners do not really know what impact IT incidents might have on their businesses. Of a pool of practitioners who have participated in a median of 20 IT incident responses over the past five years, only seven could estimate annual cumulative staff hours, and only eight could estimate the annual costs over a year. The respondents were asked to approximate, but many could not. Dillman et al. would likely recommend

that those questions be placed on an establishment survey in order to give respondents the time to research the answers[38]. Over 40% said they were not rewarded for improving IT incident management, and nearly 18% did not know. IT incidents drain business resources, and reducing this drain is difficult when those intimately familiar with them are neither aware of their significance nor encouraged to make related improvements.

7.6.3 Evaluator Comment

At one evaluation session, an Incident Coordinator mentioned that, when IT incidents of the severity she perceived the visualization addressed occurred in her firm's extensive computing services environment, the company spared no expense in responding to them. "All hands on deck" was the operative philosophy, and the best "hands" were brought in to remedy the problem. This "all-in" approach to IT incident response must inevitably impact the business beyond the measurable costs associated strictly with the IT incident, as the best people are doing high-value work when not responding. Thus the opportunity costs of the "all-in" approach may be significant for serious IT incidents.

What motivates this approach? Is it that command and control is currently so cumbersome that only the "best" can manage in the vacuum of uncertainty? Another possible explanation might be that the technical complexity would overwhelm less-qualified persons. Could an established visualization system for IT incident management reduce the number of tasks the "best" are assigned to? Could an effective visualization system allow an organization to deploy the right-sized response team and accurately match competencies to the task at hand? It is much too soon to know the answers to these questions. Is it not a management principle that if something can be measured, it is more likely to be manageable?

7.7 Summation

Over the years of intense investigation of visualization support for business leaders, much has been learned regarding their visualization needs, IT incident management, user-centered design and evaluation. Only a sampling of the results of the field study could be shared. The long-term active engagement (i.e. 80 sessions and roughly 115 hours of discussion) of a stable group of IT professionals from various organizations in both leadership and senior technical positions shows that security visualization in support of business leaders is needed and a promising line of inquiry. The ability to recruit 17 independent professionals to volunteer their time over a 50-day period in November and December is an affirmation that IT incident management is a significant problem, and that there is interest in seeing leadership supported during IT incident handling.

The findings of this research will show their significance and achieve greater clarity over time. But for now, the project demonstrates that there is benefit in security visualization research that seeks to address the significant challenges business leaders have with IT incidents that interfere with or pose imminent risk to more than one workgroup. This research has shown that decision comprehension related to security and compliance events was improved through visualization among the professionals sampled. Although the matter of improving decision awareness was left open, further research is likely to show that this can be improved as well.

CHAPTER 8. FUTURE WORK

8.1 Introduction

This project has opened a number of new avenues for security visualization research. This chapter discusses some of these possible opportunities for future investigation. These opportunities are organized primarily around the three contributions, but the first category is centered on business impact visualization. The next section focuses on further research in IT Incident Visualization System design. The following section discusses potential work related to the Iterative Field Study Methodology, and the last area of future work addresses the Practitioner-Oriented Evaluation Framework. The chapter concludes with a final discussion section.

8.2 Business Impact Visualization

Supporting leaders in understanding the impact of security and compliance events, as well as the effects related decisions may have on an organization, is an open field. The catalog of problem areas identified in this document is not complete. Beyond expanding this catalog, additional inquiries with business leaders would shed light on what the next topics of investigation should be.

8.3 IT Incident Visualization System

IT incident management is a problem space teeming with challenges related to both visualization and analysis. Additional research is needed to investigate ways to leverage pre-attentive processing to improve efficiency in establishing leader awareness of the incident and ongoing response. Investigation is needed to uncover and validate potential visual metaphors to ensure there is improvement in sensemaking among the various types of leaders. The current design of the IT Incident Visualization System prototype segregates many information dimensions of interest, and integrating these into a unified presentation may improve awareness and understanding in terms of quality and timeliness.

A related inquiry would involve investigating the relationship between cognitive needs and information presentation techniques. Although pre-attentive processing may improve, the graphical techniques needed to enable any such improvement may not be appropriate for a significant portion of the tasks leaders typically perform.

A number of visual metaphors were introduced in the prototype. Minor modifications were made to the activity diagram and Gantt chart. For these metaphors to be truly helpful, algorithms are needed to automate rendering and facilitate graphical interactivity useful for "what-if" analysis. IT incident extent is a target-rich problem area in finding effective ways to convey complex interrelationships among members within a given business environment layer, as well as between these layers.

There are a number of analytical challenges related to computing reliable IT incident measures such as IT incident urgency, direct cost, direct-cost risk, future impact on resources and response risk.

Uncertainty is a complex problem. Many decisions business leaders make are based on information that is either incomplete or has varying degrees of accuracy. Business leaders need to factor uncertainty into their decision-making, but an objective rather

than subjective approximation would be preferred. Algorithms able to provide reliable measures of uncertainty would provide additional reliable context to leaders as they perform decision-making. Computing both uncertainty and the effective presentation of this information quality attribute is a major challenge.

Usability research is needed to reduce impediments to wayfinding and sensemaking. This topic is a necessary consideration for most of the visualization challenges previously mentioned. In addition, the aggregate system needs to be considered. A useful system needs to address a very large portion of the tasks leaders perform with regard to IT incidents, which frequently exhibit unique characteristics relative to previous IT incidents. An IT Incident Visualization System may therefore need to become an adaptive toolset, allowing leaders to specify visualization needs as they arise.

Multi-platform support is another challenge. Beyond adapting visualization interfaces to the platforms' interaction paradigms, use cases for these platforms will also need to be investigated. Minimal common awareness and related tools will need to be considered. A group-wide mental model is an important objective for a multi-platform visualization. Whether a responder buried in a server rack yanking hard drives, a middle manager in a meeting, or the Incident Coordinator at her desk, all involved need an accurate common understanding of the incident and its corresponding response.

Future research should look past IT Leaders, Business Leaders and Incident Coordinators to support the Response Team Members and Stakeholders as well. Also, much work is needed to build role-oriented visualization support for the Incident Coordinator and Business Leader.

The requirements list cites a number of post-incident analysis requirements worthy of investigation. A functional visualization system would become a large knowledge base that could be mined in order to contribute to the process-improvement activities organizations perform.

Additional testing is needed to broaden and clarify the claims made in this research. Additionally, there is much to do in the area of user testing. Goodall suggests the following types of tests would be beneficial ([25],pg. 57):

- Controlled experiments comparing design elements
- Usability evaluation of a tool
- Controlled experiments comparing two or more tools
- Case studies of tools in realistic settings

8.4 Iterative Field Study Methodology

The methodology utilized was a single pass that sought validation of a conceptual goal. Going forward, some aspects of this methodology will need to be adapted for continued work toward improving the IT Incident Visualization System. Cycles will need to be added, allowing the researcher to iterate and produce intermediate outcomes suitable for independent evaluation. Once a problem space has been selected, researchers can bypass the initial stages. Further broad exploration of IT incident management would likely augment previous investigations rather than replacing completely what had been learned previously. The process of integrating old and new IT incident management task analysis will need to be carefully considered.

8.5 Practitioner-Oriented Evaluation Framework

Initially, the work on the framework was a means to an end. Given the limited availability of structured field experiment platforms for security visualization, further efforts to extend and generalize applicable use cases may be worthwhile. Investigations are needed to determine which of the various elements could be generalized for use in other evaluation or user-testing contexts. Consistent user-testing mechanisms and data sets help facilitate comparison across user-testing studies. Much of the reviewed literature

did not suggest that the tasks were progressive in nature, meaning that the current task was in some manner dependent upon a task previously performed in the evaluation. This may be due to the level of granularity at which the tasks were expressed, a detail simply left out by the author while writing, or simply a result of the tool's scope. There is benefit in user testing to emulate the progressive nature in which much of the actual work is executed.

8.6 Discussion

There is enough work to occupy multiple researchers for the lengths of their careers. Future work can be divided into strategic and design objectives.

This work is an initial investigation into the potential of a dynamic visual system as described in Section 1.4. There are a number of unverified claims within the hypothesis. The next strategic research objectives might be to do the following:

1. Conduct experiments that investigate the claims that communications, coordination and monitoring can be greatly enhanced by visualization.

2. Conduct experiments that measure and compare timeliness of awareness and comprehension relative to standard processes.

3. Conduct experiments that test the correlation of leader effectiveness with awareness and comprehension.

If a few design objectives were to be chosen for next steps, they might include:

1. Recalibrate IT Incident Visualization System requirements and priorities with a new Study Group, using the current effort as a baseline. Assuming no radical departures from the current understanding of needs and priorities, the next objectives would likely follow.

2. Develop interactive visualization of response planning, as well as resource timing and dependencies metaphors. Interaction should be centered on direct manipulation of response task objects and related sequencing for the purposes of plan construction and "what-if" plan analysis. The interaction objectives for resource timing and dependencies interaction would be similar.

3. Improve tracking of the extent of an incident's impact on each business environment layer and improve presentation of the interrelations between layers. Beyond showing past progression, providing forecasted impact expansion would be very helpful. Moreover, allow the projected extent modeling to facilitate extent-consequence assessment resulting from "what-if" response-planning activities. Forecasting direct-cost risk, project risk and the resulting urgency during these "what-if" planning exercises would complement these achievements.

4. Develop and validate algorithms or models that compute the various IT incident measures.

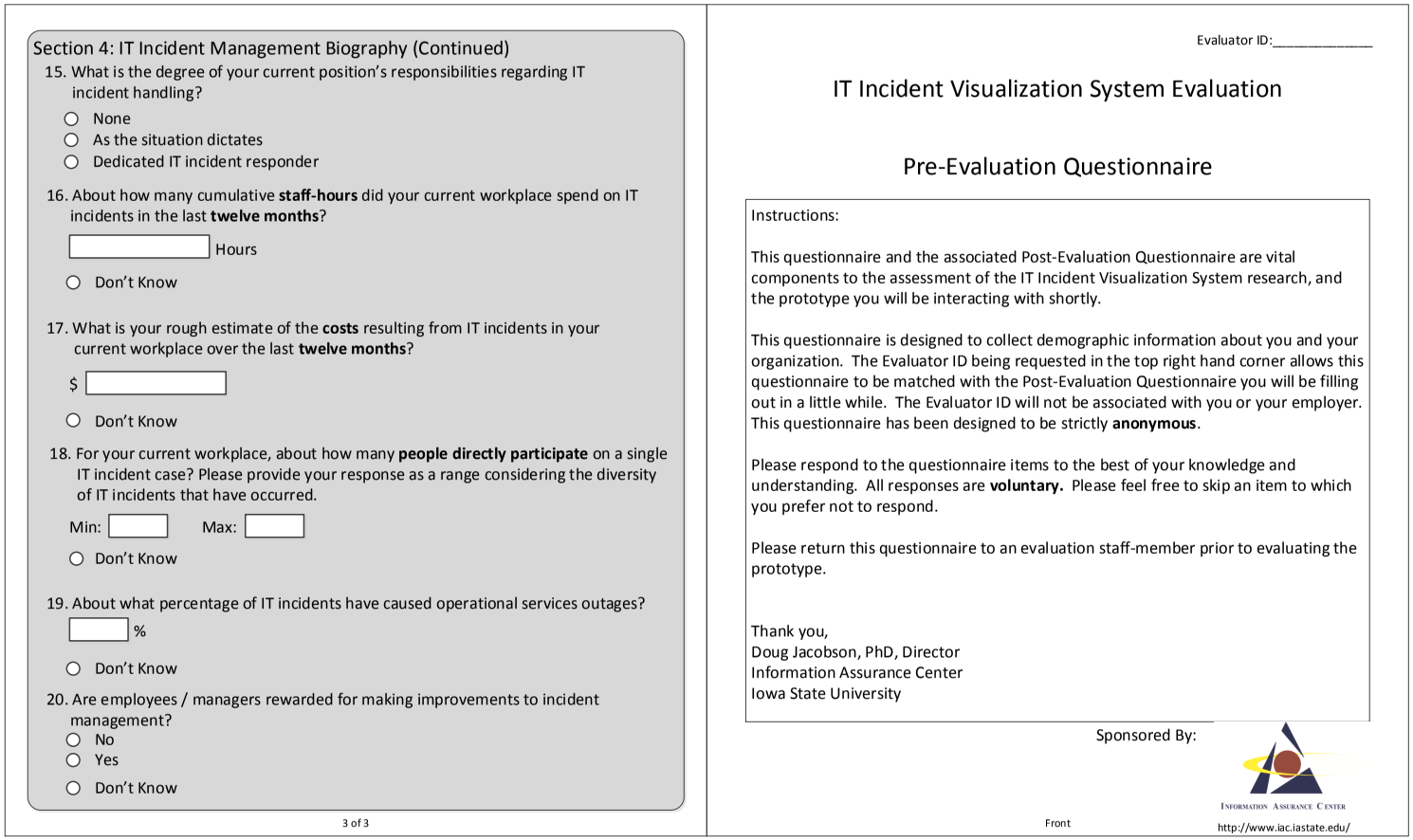
5. Develop a multi-platform visualization in support of a group mental model of IT incidents. Beyond the challenges of conducting an evaluation on multiple platforms, related evaluations would require support for multiple simultaneous evaluators, with each evaluator potentially acting in various IT incident-handling roles.

Underlying these IT Incident Visualization System design objectives are ongoing improvements to the design methodology and evaluation framework. These efforts will need to be refined and reused in order to achieve and validate the initial next steps.

For these reasons and others, future efforts in leader-oriented security visualization promise to be both challenging and rewarding.

APPENDIX A. INDUSTRY PUBLIC EVALUATION SURVEY INSTRUMENTS

This appendix contains the survey instruments used at the Industry Public Events. The surveys were designed to be printed on both sides using U.S. legal-sized paper in landscape orientation and then folded in the center.



Section 4: IT Incident Management Biography (Continued)

15. What is the degree of your current position's responsibilities regarding IT incident handling?
    - ○ None
    - ○ As the situation dictates
    - ○ Dedicated IT incident responder

16. About how many cumulative **staff-hours** did your current workplace spend on IT incidents in the last **twelve months**?

    _____ Hours

    ○ Don't Know

17. What is your rough estimate of the **costs** resulting from IT incidents in your current workplace over the last **twelve months**?

    $ _____

    ○ Don't Know

18. For your current workplace, about how many **people directly participate** on a single IT incident case? Please provide your response as a range considering the diversity of IT incidents that have occurred.

    Min: _____ Max: _____

    ○ Don't Know

19. About what percentage of IT incidents have caused operational services outages?

    _____ %

    ○ Don't Know

20. Are employees / managers rewarded for making improvements to incident management?
    - ○ No
    - ○ Yes
    - ○ Don't Know

3 of 3

Evaluator ID:_____

IT Incident Visualization System Evaluation

Pre-Evaluation Questionnaire

Instructions:

This questionnaire and the associated Post-Evaluation Questionnaire are vital components to the assessment of the IT Incident Visualization System research, and the prototype you will be interacting with shortly.

This questionnaire is designed to collect demographic information about you and your organization. The Evaluator ID being requested in the top right hand corner allows this questionnaire to be matched with the Post-Evaluation Questionnaire you will be filling out in a little while. The Evaluator ID will not be associated with you or your employer. This questionnaire has been designed to be strictly **anonymous**.

Please respond to the questionnaire items to the best of your knowledge and understanding. All responses are **voluntary.** Please feel free to skip an item to which you prefer not to respond.

Please return this questionnaire to an evaluation staff-member prior to evaluating the prototype.

Thank you,
Doug Jacobson, PhD, Director
Information Assurance Center
Iowa State University

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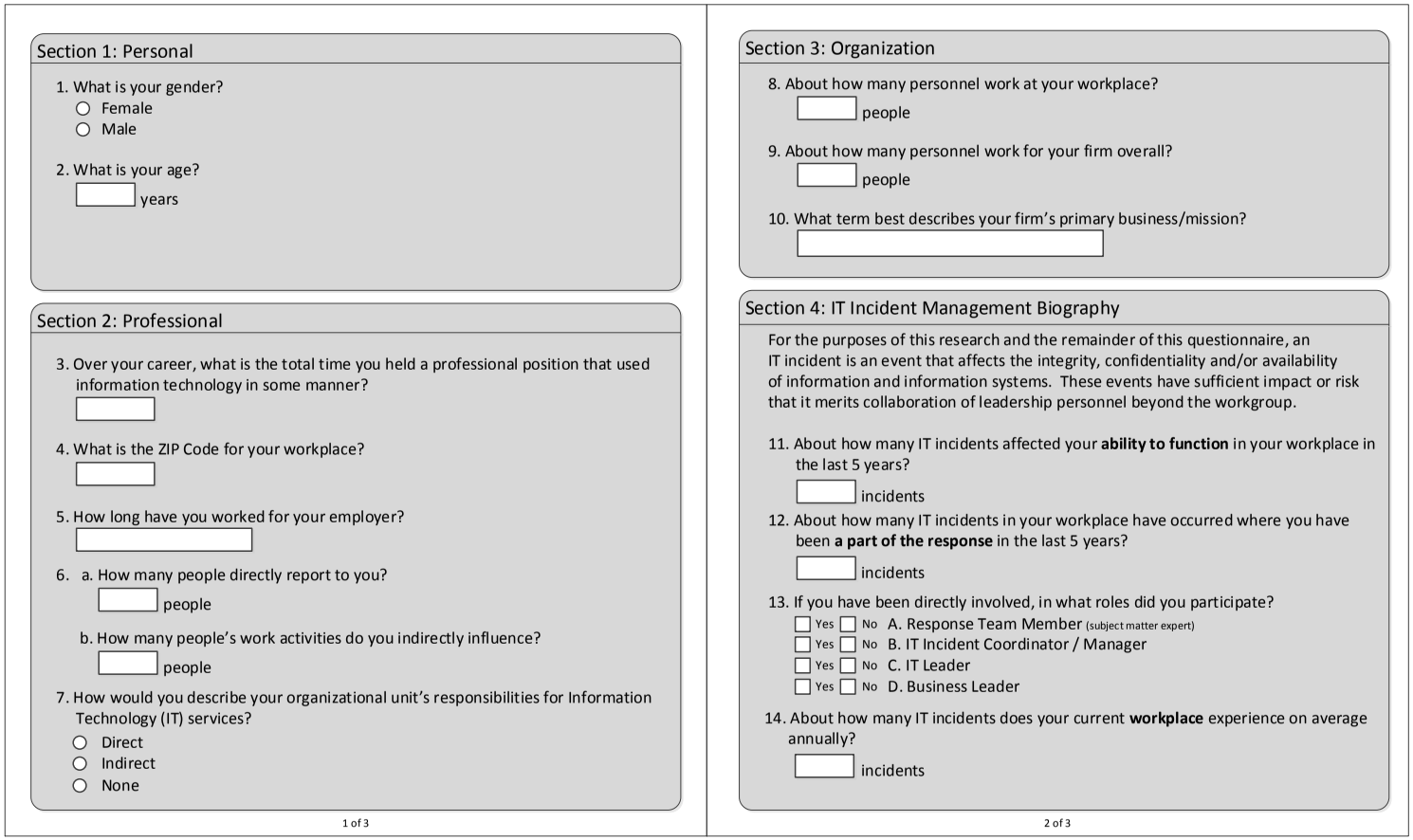
http://www.iac.iastate.edu/

Figure A.1: Pre-Evaluation Questionnaire - Front and Back Cover



Section 1: Personal

1. What is your gender?
   - ○ Female
   - ○ Male

2. What is your age?
   [ ] years

Section 2: Professional

3. Over your career, what is the total time you held a professional position that used information technology in some manner?
   [ ]

4. What is the ZIP Code for your workplace?
   [ ]

5. How long have you worked for your employer?
   [ ]

6. a. How many people directly report to you?
   [ ] people

   b. How many people's work activities do you indirectly influence?
   [ ] people

7. How would you describe your organizational unit's responsibilities for Information Technology (IT) services?
   - ○ Direct
   - ○ Indirect
   - ○ None

1 of 3

Section 3: Organization

8. About how many personnel work at your workplace?
   [ ] people

9. About how many personnel work for your firm overall?
   [ ] people

10. What term best describes your firm's primary business/mission?
    [ ]

Section 4: IT Incident Management Biography

For the purposes of this research and the remainder of this questionnaire, an IT incident is an event that affects the integrity, confidentiality and/or availability of information and information systems. These events have sufficient impact or risk that it merits collaboration of leadership personnel beyond the workgroup.

11. About how many IT incidents affected your **ability to function** in your workplace in the last 5 years?
    [ ] incidents

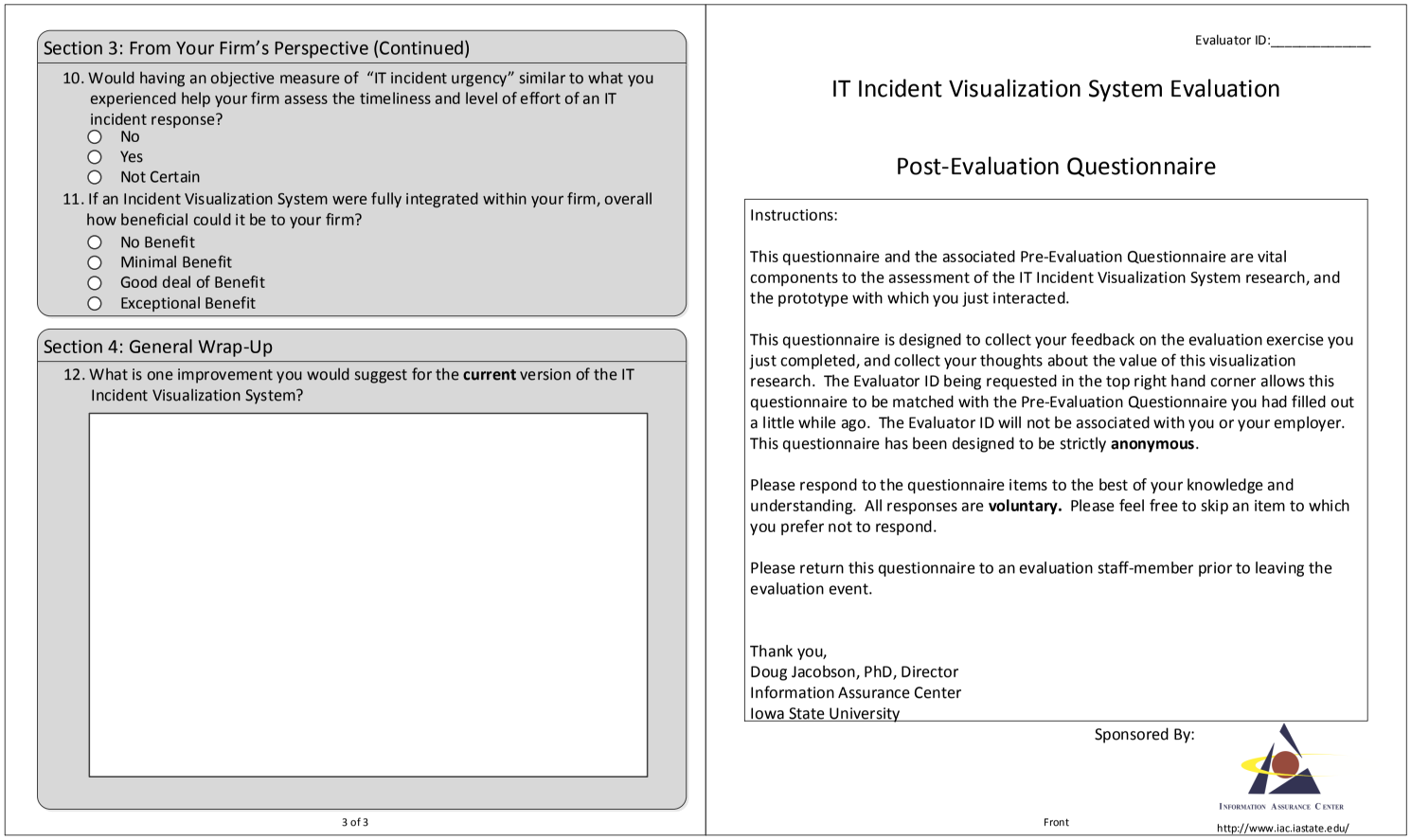
12. About how many IT incidents in your workplace have occurred where you have been **a part of the response** in the last 5 years?
    [ ] incidents

13. If you have been directly involved, in what roles did you participate?
    - ☐ Yes ☐ No A. Response Team Member (subject matter expert)
    - ☐ Yes ☐ No B. IT Incident Coordinator / Manager
    - ☐ Yes ☐ No C. IT Leader
    - ☐ Yes ☐ No D. Business Leader

14. About how many IT incidents does your current **workplace** experience on average annually?
    [ ] incidents

2 of 3

Figure A.2: Pre-Evaluation Questionnaire - Inside Pages



Section 3: From Your Firm's Perspective (Continued)

10. Would having an objective measure of "IT incident urgency" similar to what you experienced help your firm assess the timeliness and level of effort of an IT incident response?
    - ○ No
    - ○ Yes
    - ○ Not Certain
11. If an Incident Visualization System were fully integrated within your firm, overall how beneficial could it be to your firm?
    - ○ No Benefit
    - ○ Minimal Benefit
    - ○ Good deal of Benefit
    - ○ Exceptional Benefit

Section 4: General Wrap-Up

12. What is one improvement you would suggest for the **current** version of the IT Incident Visualization System?

3 of 3

Evaluator ID:_____

IT Incident Visualization System Evaluation

Post-Evaluation Questionnaire

Instructions:

This questionnaire and the associated Pre-Evaluation Questionnaire are vital components to the assessment of the IT Incident Visualization System research, and the prototype with which you just interacted.

This questionnaire is designed to collect your feedback on the evaluation exercise you just completed, and collect your thoughts about the value of this visualization research. The Evaluator ID being requested in the top right hand corner allows this questionnaire to be matched with the Pre-Evaluation Questionnaire you had filled out a little while ago. The Evaluator ID will not be associated with you or your employer. This questionnaire has been designed to be strictly **anonymous**.

Please respond to the questionnaire items to the best of your knowledge and understanding. All responses are **voluntary.** Please feel free to skip an item to which you prefer not to respond.

Please return this questionnaire to an evaluation staff-member prior to leaving the evaluation event.

Thank you,
Doug Jacobson, PhD, Director
Information Assurance Center
Iowa State University

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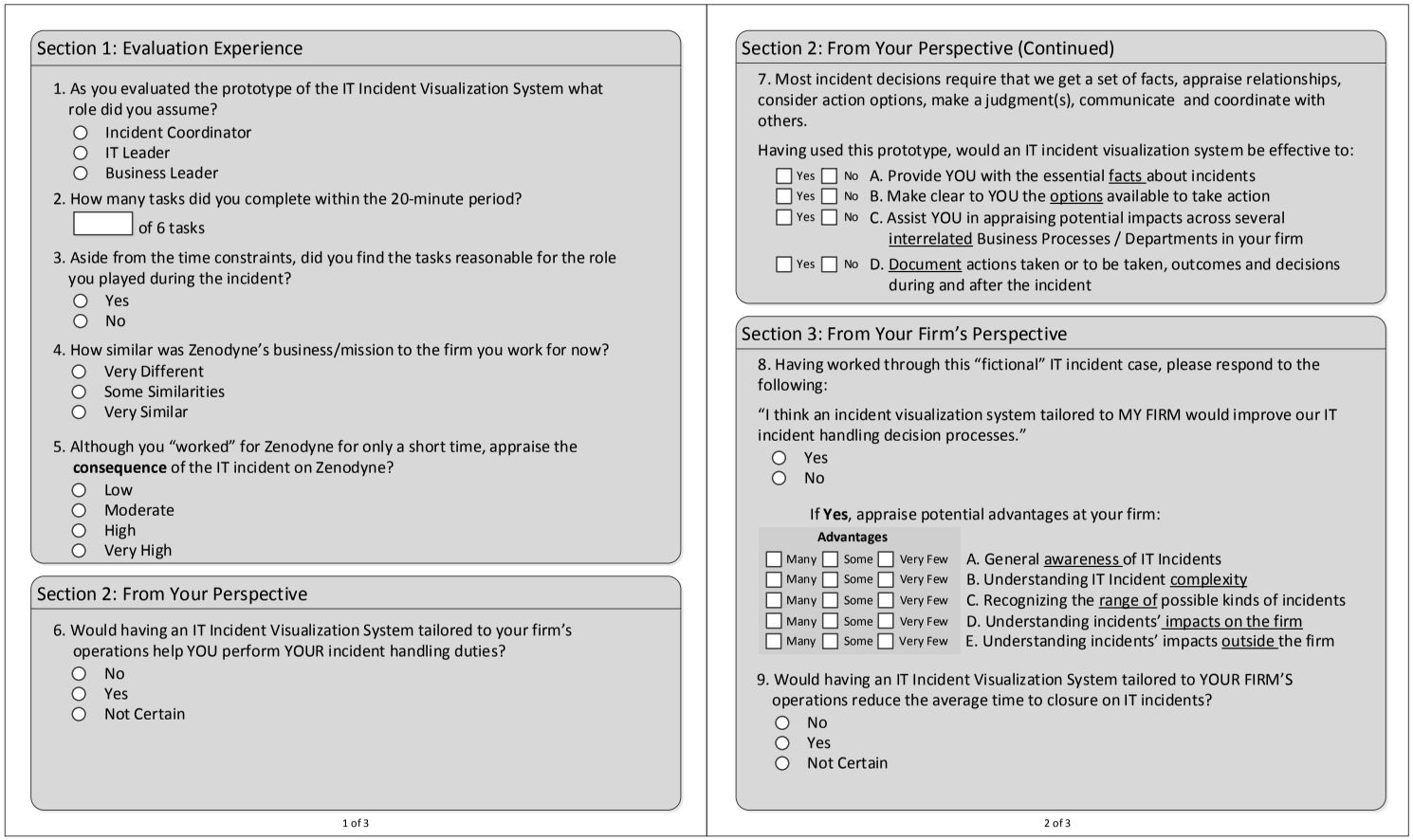
Figure A.3: Post-Evaluation Questionnaire - Front and Back Cover



Section 1: Evaluation Experience

1. As you evaluated the prototype of the IT Incident Visualization System what role did you assume?
   - ○ Incident Coordinator
   - ○ IT Leader
   - ○ Business Leader
2. How many tasks did you complete within the 20-minute period?
   ☐ of 6 tasks
3. Aside from the time constraints, did you find the tasks reasonable for the role you played during the incident?
   - ○ Yes
   - ○ No
4. How similar was Zenodyne's business/mission to the firm you work for now?
   - ○ Very Different
   - ○ Some Similarities
   - ○ Very Similar
5. Although you "worked" for Zenodyne for only a short time, appraise the **consequence** of the IT incident on Zenodyne?
   - ○ Low
   - ○ Moderate
   - ○ High
   - ○ Very High

Section 2: From Your Perspective

6. Would having an IT Incident Visualization System tailored to your firm's operations help YOU perform YOUR incident handling duties?
   - ○ No
   - ○ Yes
   - ○ Not Certain

1 of 3

Section 2: From Your Perspective (Continued)

7. Most incident decisions require that we get a set of facts, appraise relationships, consider action options, make a judgment(s), communicate and coordinate with others.

Having used this prototype, would an IT incident visualization system be effective to:

- ☐ Yes ☐ No A. Provide YOU with the essential facts about incidents
- ☐ Yes ☐ No B. Make clear to YOU the options available to take action
- ☐ Yes ☐ No C. Assist YOU in appraising potential impacts across several interrelated Business Processes / Departments in your firm
- ☐ Yes ☐ No D. Document actions taken or to be taken, outcomes and decisions during and after the incident

Section 3: From Your Firm's Perspective

8. Having worked through this "fictional" IT incident case, please respond to the following:

"I think an incident visualization system tailored to MY FIRM would improve our IT incident handling decision processes."

- ○ Yes
- ○ No

If **Yes**, appraise potential advantages at your firm:

Advantages	
☐ Many ☐ Some ☐ Very Few	A. General awareness of IT Incidents
☐ Many ☐ Some ☐ Very Few	B. Understanding IT Incident complexity
☐ Many ☐ Some ☐ Very Few	C. Recognizing the range of possible kinds of incidents
☐ Many ☐ Some ☐ Very Few	D. Understanding incidents' impacts on the firm
☐ Many ☐ Some ☐ Very Few	E. Understanding incidents' impacts outside the firm

9. Would having an IT Incident Visualization System tailored to YOUR FIRM'S operations reduce the average time to closure on IT incidents?
   - ○ No
   - ○ Yes
   - ○ Not Certain

2 of 3

Figure A.4: Post-Evaluation Questionnaire - Inside Pages

APPENDIX B. CATALOG - BUSINESS IMPACT VISUALIZATION NEEDS

This appendix contains brief descriptions of the possible business-leader-oriented visualization needs collected in Stage B of the Iterative Field Study Methodology.

Table B.1: Catalog of Business Impact Visualization Needs

Need	**Description**
Compliance and Information Risk-based Project Prioritization	When security and compliance projects undergo resource allocation evaluation or milestone slippage, managers often must re-evaluate resource allocations, project objectives and schedules. Support for this task would be related to providing security and compliance risk dimensions to project prioritization decisions. *Goal: Improve management awareness of security and compliance risk associated with project prioritization and associated deliverable schedules.*
Compliance Management	Present situational awareness regarding trending and current status of compliance assessments, as well as outstanding compliance deficiencies. Present system-oriented views associating systems with their compliance status to relevant standards and policies. *Goal: Assist business leaders with routine compliance-management decisions.*

Table B.2: Catalog of Business Impact Visualization Needs (contd.)

Need	**Description**
Compliance Attestation Support	Senior management is required by law, regulation or internal policy to attest to their organization's compliance to law, regulation or internal policies. The conceptual and perceptual distance between the"facts on the ground" and senior management introduces uncertainty to their attestation, as well as involving significant labor costs in the collection, preparation, consolidation and interpretation of supporting information. The various levels of information processing prevent senior management from having a firsthand perspective of its responsibility. Support for this task would be related to effective bridging between the ground truth and the conceptual context of the relevant senior manager. *Goal: Increase certainty in attestation; reduce time spent preparing to make an attestation.*
Problem Management	Present situational awareness regarding deviations from normal operating conditions of infrastructure systems, and facilitate decision-making regarding Business Continuity and Disaster Recovery actions and status. *Goal: Increase awareness and understanding of IT operations in order for business leaders to make necessary operations continuity decisions.*
Senior Leadership Decision Support	Decision briefing support that provides conceptual clarity for security and compliance decisions by presenting relevant technical and business data in a context consistent with each senior-level decision-maker's worldview. Cost-benefit and related risk management factors are likely aspects of the decision briefing. *Goal: Get senior decision-makers on "the same page" prior to decision-making meetings.*

Table B.3: Catalog of Business Impact Visualization Needs (contd.)

Need	**Description**
Incident Management	Present situational awareness regarding ongoing incident triage and security controls performance. Provide central view of enterprise security status, business impact of incident, and incident-handling status, and assist with evaluation between multiple incidents. *Goal: Provide business leaders sufficient context and awareness of security incidents in order for them to direct resource allocation and evaluate incident and remediation impact on business operations.*
Risk-management Option Evaluation	Present "what-if" risk calculation results during risk management option evaluation. Incorporate support for Factor Analysis of Information Risk (F.A.I.R.), adopted by The Open Group and currently being reconciled with ISO 27005, which provides a potentially useful taxonomy to be visualized. *Goal: Assist business leaders with evaluating risk-mitigation options by allowing them to observe and interpret the potential consequences of risk-mitigation option selection.*
Security Planning & Change Control	Present operational impacts of planned outages, facilitate awareness of critical applications and their dependencies, get operational change approval when needed at odd hours, and implement "what-if" analysis of control changes. *Goal: Assist business leaders with evaluating potential risk associated with control changes and the operational impacts of planned outages; streamline approval of operational decisions during odd hours.*

APPENDIX C. ANALYSIS OF TASK EXPLORATION

This appendix contains samples of various types of outcomes resulting from the analysis performed in Analysis of Task Exploration (Stage I - Section 3.2.8). The content comes from the working documents managed during this process.

Table C.1: Study Group Input Classified as Ideas

Participant	**Item**
166; 191; 270; 400; 493	A majority of incidents are operational as opposed to security-related (e.g. hack, data breach, malicious insider).
270; 400	Notification is manual, time-consuming and distracting.
270	Managerial presence among responders can increase stress if managers are asking questions that are distracting and annoying.
270; 400	[Incident status] updates are manual and time-consuming.
270	Some [incident status] updates interfere with working the issue.
270	Some [incident status] updates are a distraction.
270	Meetings involving responders and interested parties take the responders away from the actual response.
270	An incident situation is constantly evolving, so discussions should incorporate the most current possible view of the incident.
270; 400; 493	Usability Issue: some people will want personal or face-to-face interaction even if the information is available.

Table C.2: Study Group Input Classified as Ideas (contd.)

Participant	Item
270	A video briefing showing the Incident Coordinator's face in conjunction with the information may address this usability issue to some degree.
400	WebEx tool and Sharepoint are successful tools in communicating incident information in this participant's environment.

Table C.3: Study Group Input Classified as Decisions

Participant	Item
270	Whether or not the incident is malicious.
270	Do we do something now or not?
270	What it is? Or, What is going on?
270	Who is affected?
270	What are the response options?
270	Choosing a response option.
270	Locating and assigning resources to the response.
400	Upon awareness, how does this incident affect what I am responsible for?
400	How do we best serve the business?
166;400	Should a business unit be contacted?

Table C.4: Analysis Results Classified as Notions

Item Label	Item
1	While other organizations experience significant resource losses to large incident response efforts, only large organizations can afford and justify the need for dedicated incident management staff. These resource losses affect previously scheduled work and have an ongoing impact on this work after incident closure, due to compensating employees for their long hours and time away from home. These ongoing effects are dependent on the organization's culture and compensation policies.
2	Incidents happen.
3	Operational incidents are much more frequent than security incidents, possibly at a 9:1 ratio or even less frequently.
4	For most personnel, incident handling or being a part of the response process is an activity overlaid on top of workload laid out in advance.
5	Individual business leaders (not part of IT) experience incidents infrequently. Security incidents are even more rare events for business leaders.
6	Incomplete information is commonplace for significant decisions. This can be the result of an incomplete presentation of available data to the decision-maker or from an incomplete understanding due to the incident's complexities.
7	Level of urgency drives timeliness and resource allocation for a response.
8	Business impact is a highly influential factor for urgency.
9	Financial considerations of an incident and remediation are the foundations of leadership decision-making during incident response.
10	Financial considerations are based on cost accounting that addresses the direct and indirect costs of the incident. Direct costs are challenging to compute in the heat of an incident. Indirect costs such as effects on reputation may be impossible to compute within the time horizon of an incident.

Table C.5: Analysis Results Classified as Principles

Notion IDs	**Principle**
76,77,87,43	A poorly planned or unduly influenced response plan may exacerbate impact as well as delay the incident's closure. Response planning is necessary in order to evaluate potential effectiveness, timeliness, cost, required resources, action coordination and communication, and meeting the expectations of those external to the response team. Due to unexpected outcomes and constraints, response plans are subject to change as incident response progresses. Response planning and communication is a time investment that is proportional to the combination of incident clarity, complexity, scope and severity. Leaders who are unfamiliar with or lack an understanding of the response plan may find the selected approach to be less "direct" than they would wish and may attempt to influence the plan. Understanding leaderships' risk-tolerance profile may allow incident-response planners to anticipate those response options that will be approved prior to submitting them, as well as to prioritize efforts more in alignment with leadership's expectations. Avoiding the construction of suggestions that are unlikely to be approved or that may be subject to extensive revision saves time and improves response timeliness. Compliance, customer service and financial considerations are more significant factors than technical merits in response plan evaluation.
18,70,71,78	Mature incident management integrates responses to all incident classes into a common handling framework. Each class of incident (operational, security, compliance) has a general response structure. As the class of incident is determined, an appropriate response team is assembled and one of these response structures is carried out.

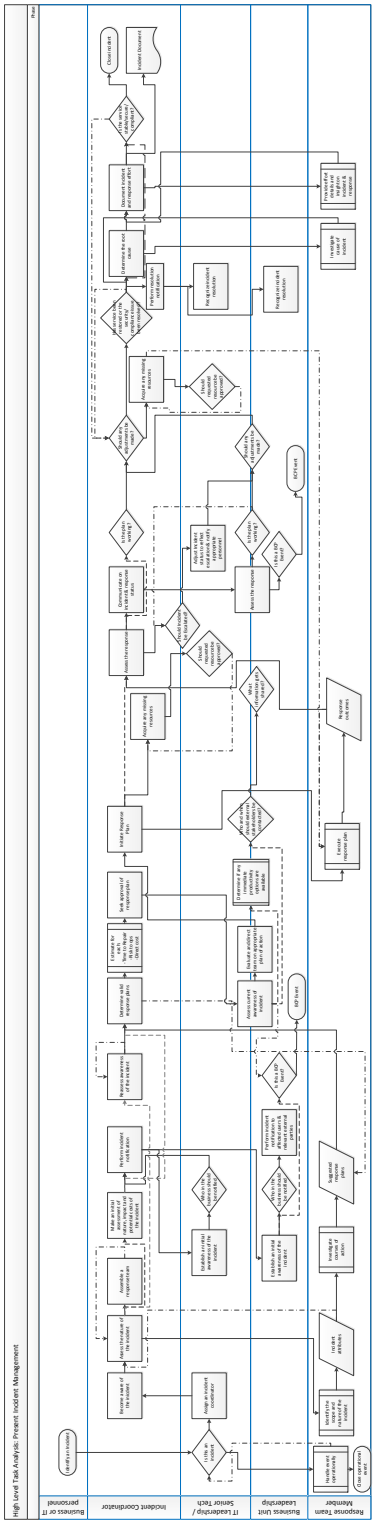
Table C.6: Analysis Results Classified as Principles (contd.)

Notion IDs	**Principle**
94,95,21,91,89,90	Compliance is an immediate and ongoing consideration for all incidents. Compliance awareness, interpretation and understanding may not occur until after the incident, given that compliance expertise may not reside with the response team, thus presenting communication limitations. Compliance is viewed as a requirement. Executive management will consider compliance consequences when an incident's scope or impact is sufficiently large. Incidents involving persistent compliance controls will be handled with urgency and care. A gap in persistent controls operations is permanent. Beyond persistent controls, compliance is commonly determined by the affected systems/services and the data that is contained within those systems. Business units are commonly aware of which compliance considerations are relevant to their systems. Compliance issues can typically be ruled in or out as the scope or extent of the incident is determined. Any expansion or shifting of the scope of the incident will require that compliance be reconsidered.

APPENDIX D. IT INCIDENT MANAGEMENT TASK STRUCTURES AND FLOW

The first diagram is a flow chart depicting how the various core IT incident response roles interact with each other. The diagram was originally designed to span two 17" x 11" sheets, so is a bit hard to read when printed. The image has been saved with sufficient resolution to read labels when zoomed.

A number of task-structure diagrams were produced during Stage J (Section 3.2.9); this is one example. The diagram was originally designed to span two 11" x 8 $\frac{1}{2}$" sheets, so is a bit hard to read when printed. The image has been saved with sufficient resolution to read labels when zoomed.


High Level Task Analysis: Prepare Incident Management
Business or IT personnel
Incident Coordinator
IT Leadership / Senior Tech
Business Unit Leadership
Response Team Member
Start
Need to initiate?
Receive news of incident
Assign an incident coordinator
Is this an incident?
Close ticket
Open incident ticket
Assemble a response team
Make an initial assessment of the severity of the incident
Escalate to senior technical support
Is this a high severity incident?
Escalate to IT leadership
Is this a high severity incident?
Escalate to business unit leadership
Is this a high severity incident?
Escalate to response team member
Is this a false alarm?
Close ticket
Inform awareness of the event
Determine and declare incident
Contact the 24/7 Security Threat Response Service
Task approval of response
Initiate response plan
Assess current impact of incident
Evaluate and direct response
Examine and remediate malware on affected assets
Task approval of response
Initiate response plan
Assess current impact of incident
Evaluate and direct response
Examine and remediate malware on affected assets
Task approval of response
Initiate response plan
Assess current impact of incident
Evaluate and direct response
Examine and remediate malware on affected assets
Task approval of response
Initiate response plan
Assess current impact of incident
Evaluate and direct response
Examine and remediate malware on affected assets
Task approval of response
Initiate response plan
Make an initial assessment of the severity of the incident
Inform incident coordinator
Make an initial assessment of the severity of the incident
Inform incident coordinator
Make an initial assessment of the severity of the incident
Inform incident coordinator

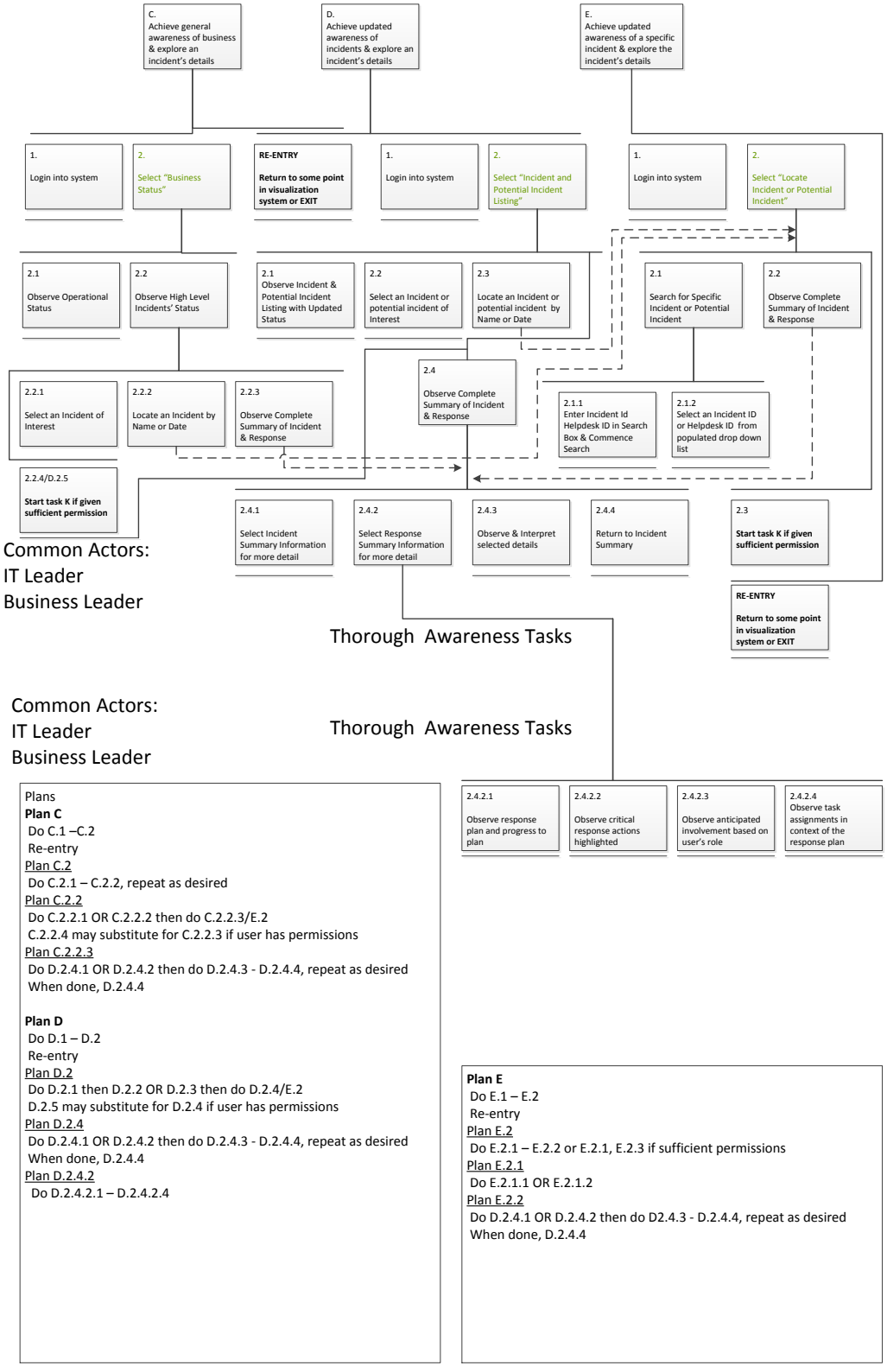


Figure D.2: Sample Task Structure and Plan

APPENDIX E. IT INCIDENT VISUALIZATION SYSTEM REQUIREMENTS

The requirements presented in this appendix were developed in Stage K (Section 3.2.10) and revised in Stage M (Section 3.2.12). The requirements were developed to be hierarchical. The first table contains the high level requirements. The remaining tables contain more granular requirements that expand on each of the high-level requirements.

Table E.1: High-Level Requirements

Label	Name and Description
1	**Incident Handling Awareness** Augment perception of each and all incidents' character and response efforts related to those incidents through the presentation of appropriate information.
2	**Decision Support** Provide support for decision, assessment, evaluation, and choice tasks performed by the visualization system user (hereafter to be referenced as the user), so that correct judgment/decision tasks are performed in an informed and timely manner.
3	**Communication Capability** Provide an incident's "community of interest" a means to inform and be informed of incident attributes and corresponding response characteristics (e.g. actions, response outcomes, response resources, task assignments and plans). The "community of interest" consists of individuals assigned to incident dependent roles of: Incident Coordinator, Response Team Member, IT Leader, Business Leader, Stakeholder, Internal Affected User, External Entities (e.g. Customer/Client, Partner, Regulator).

Table E.2: High-Level Requirements (contd.)

Label	Name and Description
4	**Coordination Capability** Provide a means to facilitate the acquisition of human and technical resources as well as direct these resources in order to mount and deliver an effective and timely response in coordination with response plans, procedures, policy and relevant regulatory requirements.
5	**Incident Actions Guide** Provide incident handling process guidance to visualization system users.
6	**Incident Measures** Provision of understood, accepted and reliable incident indicators.
7	**Incident Review & Analysis Tools** Provide a means to interact and visualize historical incident management data.
8	**Incident Handling Documentation** Provide a record of incident details and response actions taken. Primary uses are awareness among active responders and historical needs like internal reporting, legal and compliance needs, cost accounting and more.
9	**Visualization Usability** Exhibit the qualities of being easy to use, learnable and useful.

Table E.3: 1 - Incident Handling Awareness Design Requirements

Label	Name and Description
1	**Incident Handling Awareness** Augment perception of each and all incidents' character and response efforts related to those incidents through the presentation of appropriate information.
1.A	*Status* Presentation of the **present** state or condition of active incidents and their corresponding responses expressed in terms of quantitative (i.e. values resulting from measurements or calculations), temporal (i.e. related to time), relational, conceptual and verbal (i.e. textual) information.
1.B	*Progression* Presentation of the **succession** of status information elements for incidents and their corresponding responses. Status is as described in requirement 1.A.
1.C	*Report* A structured snapshot presentation of the status, as defined in 1.A, and progression, as defined in 1.B. The structure of presented information is dictated by the awareness objectives for each report type. Snapshot means that once an instance of this awareness type is released the information contained therein is unchanging.

Table E.4: 2 - Decision Support Design Requirements

Label	Name and Description
2	**Decision Support** Provide support for decision, assessment, evaluation, and choice tasks performed by the visualization system user (hereafter to be referenced as the user), so that correct judgment/decision tasks are performed in an informed and timely manner.
2.A	*Judgment/Decision Task Awareness* Provide user awareness of a pending decision, assessment, evaluation, estimation, or choice task he or she is responsible to perform.
2.B	*Information Support* Provide user access to data that enables a pending judgment/decision task (i.e. decision, estimation, assessment, evaluation, or choice) or facilitate the search or request for missing data.
2.C	*Uncertainty Support* Provide a means to gauge uncertainty through an expression of a) information incompleteness, b) reliability of measurement and calculation, or c) projected value variability of presented information.
2.D	*Projection* Provide an expression of one or more possible future outcomes/values of incident attributes and indicators based on current information, models of incident dynamics and response team judgments.

Table E.5: 3 - Communication Capability Design Requirements

Label	Name and Description
3	**Communication Capability** Provide an incident's "community of interest" a means to inform and be informed of incident attributes and corresponding response characteristics (e.g. actions, response outcomes, response resources, task assignments and plans). The "community of interest" consists of individuals assigned to incident dependent roles of: Incident Coordinator, Response Team Member, IT Leader, Business Leader, Stakeholder, Internal Affected User, External Entities (e.g. Customer/Client, Partner, Regulator).
3.A	*Intra Core* Provide communication capability among core incident response roles (i.e. Incident Coordinator, Response Team Members, IT Leadership, Business Leadership, Stakeholders). People assigned to these core incident response roles will have interactive access to the visualization system. Access governance is outside of this requirement's scope.
3.B	*Interactive Internal Users* Provide communication capability between the core incident response roles and the affected internal user population. People assigned to the internal user group will have interactive access to the visualization system. Access governance is outside of this requirement's scope.
3.C	*Interactive External Entities* Provide communication capability between the core incident response roles and the affected external user population and regulatory entities. External user population is defined as those users who are not employees or function on behalf of the organization (e.g. customers, partners). People assigned to the external entity groups will have interactive access to the visualization system. Access governance is outside of this requirement's scope.
3.D	*Passive Non-Core Actors* Provide communication **from** the core incident response roles **to** the affected non-core actors. Non-core actors are defined as those assigned to incident response roles not identified in 3.A. People assigned to the non-core roles will **not** have interactive access to the visualization system.

Table E.6: 4 - Coordination Capability Design Requirements

Label	Name and Description
4	**Coordination Capability** Provide a means to facilitate the acquisition of human and technical resources as well as direct these resources in order to mount and deliver an effective and timely response in coordination with response plans, procedures, policy and relevant regulatory requirements.
4.A	*Response Resource Acquisition* Provide a means to request the acquisition of resources (e.g. internal personnel, software, tools & equipment, consultants or contractors, improved manufacturer support) and facilitate request approval decisions.
4.B	*Response Resource Tasking* Enable the Incident Coordinator or authorized leader to direct/assign resources to tasks and monitor assignment loads and completion of tasks. Enable task escalation when task completion is past due beyond a configured time threshold. Note: Monitoring of progress is not limited to the Incident Coordinator.
4.C	*Incident & Response Judgment/Decision Escalation* Enable automated and manual escalation of an entire incident or specific related response judgments/decisions. Performance of manual escalation is limited to authorized visualization users. Escalation will manifest itself in escalation notification (both in-band and out-of-band), visual indication, role assignment adjustments, task & judgment/decision queue changes and changes in level of concern for relevant personnel. Escalation automation will be specified in a requirement subordinate to this requirement; however, in general this functionality will focus on triggers based on the individual incident and its related response status.
4.D	*Response Role Management* Provide the Incident Coordinator or authorized visualization user the ability to assign human resources to incident response roles. Provide authorized visualization users visibility into who has been assigned to which roles and their contact information.

Table E.7: 4 - Coordination Capability Design Requirements (contd.)

Label	Name and Description
4.E	*Timeline and Dependency Awareness* Present resource availability constraints in the context of active and pending tasks. Emphasize task sequences at risk of violating resource availability constraints or allowing resources to idle beyond a specified threshold. Emphasize resource assignments that violate availability constraints. Provide a view of identified response resources with their corresponding availability constraints, their current status and time remaining until the next state transition (i.e. leaving the response effort, joining the response effort).

Table E.8: 5 - Incident Actions Guide Design Requirements

Label	Name and Description
5	**Incident Actions Guide** Provide incident handling process guidance to visualization system users.
5.A	*Incident plan support* Present the approved incident response plan accentuating a) critical points in the plan, b) assigned tasks of all types, c) user's anticipated involvement based on his or her assigned response role and d) current progress of plan.
5.B	*Policy and Guidelines* Present relevant excerpts of Policy highlighting passages related to specified responsibilities associated with the user's assigned response role. Present relevant guidelines and highlighting passages related to responsibilities associated with user's assigned response role.
5.C	*Compliance concerns* Present relevant compliance concerns identified by incident attribute correlation as well as those suggested by compliance subject matter experts.
5.D	*Out-of-band notification* Initiate out-of-band communication to provide reminders of pending or past due task assignments and upcoming critical points in the response. Out-of-band as term means using an existing communications method other than the visualization.

Table E.9: 6 - Incident Measures Design Requirements

Label	Name and Description
6	**Incident Measures** Provision of understood, accepted and reliable incident indicators.
6.A	*Time* Time is an attribute of the progression of events. Various devices define time in conventional units of measure. The visualization will present: a) time of occurrence, b) time of cessation, c) duration and d) time remaining before expected cessation or occurrence of an event, action or task. Note: No granularity constraints are implied on events, actions or tasks referenced in this requirement.
6.B	*Direct Incident Cost* A measure of **present** accumulated direct accounting incident costs associated with a) resources committed to incident resolution, b) hardware replacement costs, c) lost productivity, d) measurable contractual penalties and e) degraded revenue related processes. Note: Punitive and regulatory fines and judgments are not included due to the high degree of uncertainty of the actual associated costs will be when determined months or years in the future. These costs are deemed to be indirect costs.
6.C	*Direct Incident Cost Risk* The most likely cost rate (e.g. $/hr) projection of expected direct incident cost as defined in 6.B.
6.D	*Extent* Indicator of directly affected business processes, systems, data and personnel at present. Indicator of presently unaffected business processes, systems, data and personnel with known dependencies on presently affected business processes, systems, data and personnel.
6.E	*Urgency* A time varying incident indicator that reflects the curvature of the direct incident cost risk projection, response plan execution risk, and exposure to security, compliance and brand.

Table E.10: 7 - Incident Review & Analysis Tools Design Requirements

Label	Name and Description
7	**Incident Review & Analysis Tools** Provide a means to interact and visualize historical incident management data.
7.A	*Incident Management Improvement* Provide an interactive capability that provides a "look-back" or detailed review of **an** incident and related response for the purposes of improving incident handling processes and incident prevention. Provide an interactive capability that provides analysis support for visualization user selected **collections** of incidents for the purposes of improving incident handling processes and incident prevention. Note: Listing lines of inquiry for support of process improvement and incident prevention will be specified in subordinate requirements.
7.B	*Institutional Incident Knowledge Management* Provide management and incident responders knowledge delivery mechanisms of historical incident data in order to provide an interactive data presentation of historical incident data for active incident responders, response training and to assist with incident awareness training.
7.C	*Control Change Evaluation* Provide an interactive data presentation to assist with determining the efficacy of current technical controls and the potential consequences of technical control changes in the context of past managed incidents. Note: Control changes have been potentially determined to be the root cause of past incidents. This line of inquiry will be supported in 7.A.
7.D	*Business Resilience Improvement Support* Provide an interactive data presentation to assist with assessing adaptability and recovery performance of business processes, systems, and human resource based on past incident data. Provide support for anticipating similar incidents within business processes, systems, and human resources based on past incident data.

Table E.11: 8 - Incident Handling Documentation Design Requirements

Label	Name and Description
8	**Incident Handling Documentation** Provide a record of incident details and response actions taken. Primary uses are awareness among active responders and historical needs like internal reporting, legal and compliance needs, cost accounting and more.
8.A	*Decision Making* Record decisions made along with available information and assumptions the decision-maker shares with the visualization system.
8.B	*Response Actions* Chronicle tasks performed and their durations, task outcomes, and task performers.
8.C	*Response Plans* Archive proposed response plans, chosen plans and any later adjustments to plans. Management sign-off on plan acceptance and changes will be required and recorded. Rationale for choices and later adjustments are recorded as well.
8.D	*Incident Nature* Journal incident attributes and measures periodically and at key events.

Table E.12: 9 - Visualization Usability Design Requirements

Label	Name and Description
9	**Visualization Usability** Exhibit the qualities of being easy to use, learnable and useful.
9.A	*Convenience* Provide centralized access to authoritative incident management data as well as easy to use task relevant data access and submission mechanisms.
9.B	*Information Relevance* Provide information the visualization user considers relevant or has a "desire to know" based on established level-of-concern or the current response role of the user. This requirement applies to all forms of information presentation delivered or initiated by the visualization system. "Desire to know" will govern information presentation priorities of information drawn from the pool of information authorized for user access. This information pool is managed by the "need to know" security principle. Information authorization will be manageable by authorized visualization users.
9.C	*Accessible* Provide support for multiple platform types (e.g. desktop/laptop, tablet computer, smart phone) with at least one able to support the visualization user away from his or her desk. At least one platform type will be resilient to the lack of a nearby source of electrical power and support multiple communication paths (e.g. wired/WI-FI Ethernet, mobile phone carrier data services) in the event of LAN unavailability. All visualization platforms will have a user interface sensitive to human factors and work environment limitations.
9.D	*Functional Relevance* Provide an interaction experience that is sensitive to a) the user's training with the visualization (i.e. "competency to perform") and b) the user's "need to perform" that is a consideration of both response role responsibilities and the context of visualization task objectives. This requirement applies to all visualization platforms. The notions of "need to perform" and "competency to perform" will govern access priorities to functions or capabilities drawn from the pool of authorized actions, capabilities and functions. This pool is managed by the "least privilege" security principle. Action, capability and function authorization will be manageable by authorized visualization users.

APPENDIX F. REQUIREMENTS RANKING MATERIALS

Several documents were sent to Study Group members in an email. One document contained the requirements listed in Appendix E. The second document contained instructions as well as the forms Group members used to indicate their pairwise ranking preferences.

Business Impact Visualization for Security and Compliance Events - Incident Management

Design Requirements Ranking

Introduction

With your help, I believe a credible set of design requirements have been identified. In order to further align my research to organizations like yours, I need to determine the priority to place on each of these design requirements. This requirements ranking effort will help me do just that.

Instructions

Mechanically, the process involves choosing which requirement has importance over another and expressing the level importance or intensity on a scale provided. A 9-point intensity scale appears between each pair of design requirements. Each number of the intensity of importance scale has been assigned a meaning. Descriptions for each scale value are provided in the following table.

Intensity of Importance	Definition	Explanation
1	Equal importance	Two requirements contribute equally to the objective.
3	Weak importance of one over another	Experience and judgment slightly favor one requirement over the other
5	Essential or strong importance	Experience and judgment strongly favor one requirement over the other
7	Very strong importance or demonstrated importance	A requirement is favored very strongly over another; its dominance demonstrated in practice
9	Absolute importance	The evidence favoring one requirement over another is of the highest possible order of confirmation
2,4,6,8	Intermediate values between two adjacent scale values	When compromise is needed

Table 1: Intensity of Importance Scale

Revision: 20110209

Figure F.1: Ranking Instructions - Page 1

You are welcome to revise your responses prior to submitting them to me. You are also welcome to perform the requested comparisons in any order, but please respond to all of them. Please distinctively mark your choices directly on the comparison forms to ensure data integrity.

Please enter your study participant ID number on each page so that each submission remains properly collated. Your participant ID can be found in the cover email to which this document was attached.

Beyond the mechanics of the comparison process, there are many points of view one can take when performing the comparisons. Although each may be generally valid, an uncoordinated set of viewpoints will raise uncertainty with the ranking results and reduce the reliability of these research results. Your ranking efforts will be most useful when you make your choices from the perspective of what I call the Comparison Criteria.

Comparison Criteria

Please, consider that the focus of this visualization research is to answer the question of whether it is possible to improve leaders' (i.e. incident leader, IT leader, business leader) awareness and comprehension of incident management decisions through a dynamic visual system. Not all of these leader types have the same needs for each requirement. In the cover email, you will find that a leader type that has been assigned to you.

From the perspective of your leader context, choose from each pair the design requirement that you feel is more important for the incident management visualization to incorporate in order to improve incident management performance in your organization. Indicate the level of importance intensity by selecting a value that you feel best describes the significance of your requirement choice.

Revision: 20110209

Figure F.2: Ranking Instructions - Page 2

Exploring a Comparison In Detail

Pairwise comparison is an evaluation of importance of one requirement over another expressed as a level of importance intensity. Each pair of requirements appears only **once** in the comparison forms attached.

The example below shows how the Comparison Criteria and the pairwise comparison work together.

Example

Comparison Criteria: As a parent within your household determine the importance of the following attributes of ice cream you consider when selecting ice cream at the grocery store for your family.

No. 0 Ice cream **flavor** 9 8 7 6 5 4 3 2 *1* 2 3 4 5 6 7 8 9 Ice cream **calories**

Since the assignment of requirements to the left or right sides is arbitrary, you may have the following alternative presented and the selections made have identical meaning as the first presentation above.

No. 0 Ice cream **calories** 9 8 7 6 5 4 3 2 *1* 2 3 4 5 6 7 8 9 Ice cream **flavor**

*Comparison Interpretation: In both cases, as a parent of my household I consider ice cream **flavor** has a very strong importance **over** ice cream **calories** when selecting ice cream at the grocery store for my family .*

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Figure F.3: Ranking Instructions - Page 3

Requirement Meaning

A description of each requirement you are comparing is provided in an accompanying document. Many requirement names and descriptions have changed based on your input during the Requirements Review. So, please base your ranking of each requirement on what is currently written for each requirement and the visualization context we discussed. In most cases the general gist remains the same for each requirement, and hopefully the language changes added precision and clarity. Feel free to contact me (mtannian@iastate.edu) if you need anything clarified.

Response Submission

There are several ways we can coordinate submission of your ranking efforts: 1) the forms can be scanned and emailed, 2) the forms can be mailed to me (a self-addressed stamped envelope is available upon request) or 3) I can stop by your office to pick up your submission.

Time Frame

Although your "mileage may vary", I hope the comparison process will take you an hour to complete. I would like to get your submissions 1 week from when you received this form.

Comparison Organization

The comparisons have been organized into 10 independent sets of comparisons. The first set consists of comparisons between high-level design requirements. The remaining nine groupings are sets of decomposed requirements that align to each of the high-level design requirements. The priority assigned to each high level design requirement will weight the priority of each of the related more detailed requirements.

Comparison Outcome

The relative importance intensities you assign will be analyzed through a mathematical technique. The results will be the priority you assigned to each of the requirements. These results will then be combined with the priority judgments made by the other study participants to determine a study-wide priority of requirements.

Revision: 20110209

Figure F.4: Ranking Instructions - Page 4

Please write your assigned leader context here: _____

Pairwise Comparison Set: High Level Design Requirements

		Importance									Importance									
No. 1	Incident Handling Awareness	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Review & Analysis Tools
No. 2	Coordination Capability	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Review & Analysis Tools
No. 3	Communication Capability	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Coordination Capability
No. 4	Incident Actions Guide	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Handling Awareness
No. 5	Decision Support	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Visualization Usability
No. 6	Coordination Capability	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Handling Awareness
No. 7	Incident Handling Awareness	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Communication Capability
No. 8	Coordination Capability	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Actions Guide
No. 9	Incident Actions Guide	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Decision Support
No. 10	Communication Capability	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Actions Guide
No. 11	Decision Support	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Coordination Capability
No. 12	Visualization Usability	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Handling Awareness
No. 13	Visualization Usability	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Communication Capability
No. 14	Incident Actions Guide	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Visualization Usability
No. 15	Incident Measures	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Handling Awareness
No. 16	Communication Capability	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Review & Analysis Tools
No. 17	Incident Handling Awareness	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Handling Documentation
No. 18	Decision Support	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Handling Awareness
No. 19	Incident Review & Analysis Tools	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Handling Documentation
No. 20	Incident Measures	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Actions Guide
No. 21	Visualization Usability	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Review & Analysis Tools
No. 22	Communication Capability	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Decision Support
No. 23	Coordination Capability	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Handling Documentation
No. 24	Incident Actions Guide	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Review & Analysis Tools
No. 25	Incident Handling Documentation	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Visualization Usability
No. 26	Visualization Usability	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Measures
No. 27	Visualization Usability	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Coordination Capability
No. 28	Incident Handling Documentation	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Actions Guide

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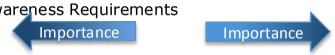
Figure F.5: Ranking Instructions - Page 5

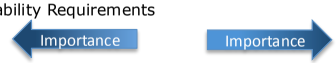
No. 29	Incident Review & Analysis Tools	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Measures
No. 30	Decision Support	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Handling Documentation
No. 31	Incident Review & Analysis Tools	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Decision Support
No. 32	Decision Support	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Measures
No. 33	Incident Measures	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Communication Capability
No. 34	Incident Handling Documentation	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Measures
No. 35	Coordination Capability	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Measures
No. 36	Communication Capability	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Handling Documentation

Pairwise Comparison Set: Incident Handling Awareness Requirements



No. 1	Progression	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Report
No. 2	Status	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Report
No. 3	Progression	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Status

Pairwise Comparison Set: Communication Capability Requirements



No. 1	Interactive External Entities	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Interactive Internal Users
No. 2	Interactive Internal Users	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Intra Core
No. 3	Intra Core	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Interactive External Entities
No. 4	Passive Non-Core Actors	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Intra Core
No. 5	Passive Non-Core Actors	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Interactive Internal Users
No. 6	Interactive External Entities	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Passive Non-Core Actors

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Figure F.6: Ranking Instructions - Page 6

Pairwise Comparison Set: Coordination Capability Requirements

		Importance									Importance								
No. 1	Response Role Management	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Timeline and Dependency Awareness
No. 2	Timeline and Dependency Awareness	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Response Resource Tasking
No. 3	Response Resource Acquisition	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident & Response Judgment/Decision Escalation
No. 4	Response Resource Acquisition	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Response Role Management
No. 5	Incident & Response Judgment Escalation	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Timeline and Dependency Awareness
No. 6	Response Resource Tasking	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident & Response Judgment/Decision Escalation
No. 7	Response Role Management	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident & Response Judgment/Decision Escalation
No. 8	Response Resource Acquisition	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Response Resource Tasking
No. 9	Timeline and Dependency Awareness	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Response Resource Acquisition
No. 10	Response Resource Tasking	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Response Role Management

Pairwise Comparison Set: Decision Support Requirements

		Importance									Importance								
No. 1	Information Support	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Judgment/Decision Task Awareness
No. 2	Uncertainty Support	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Information Support
No. 3	Projection	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Uncertainty Support
No. 4	Information Support	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Projection
No. 5	Uncertainty Support	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Judgment/Decision Task Awareness
No. 6	Judgment/Decision Task Awareness	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Projection

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Figure F.7: Ranking Instructions - Page 7

Pairwise Comparison Set: Incident Actions Guide Requirements

		Importance									Importance								
No. 1	Compliance Concerns	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Out-of-Band Notification
No. 2	Policy and Guidelines	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Compliance Concerns
No. 3	Incident Plan Support	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Compliance Concerns
No. 4	Out-of-Band Notification	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Policy and Guidelines
No. 5	Policy and Guidelines	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Plan Support
No. 6	Incident Plan Support	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Out-of-Band Notification

Pairwise Comparison Set: Incident Measures Requirements

		Importance									Importance								
No. 1	Direct Incident Cost	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Time
No. 2	Extent	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Direct Incident Cost
No. 3	Time	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Extent
No. 4	Extent	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Urgency
No. 5	Urgency	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Time
No. 6	Direct Incident Cost Risk	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Direct Incident Cost
No. 7	Urgency	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Direct Incident Cost Risk
No. 8	Time	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Direct Incident Cost Risk
No. 9	Direct Incident Cost	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Urgency
No. 10	Direct Incident Cost Risk	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Extent

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Figure F.8: Ranking Instructions - Page 8

Pairwise Comparison Set: Incident Review & Analysis Tools Requirements

		Importance									Importance								
No. 1	Incident Management Improvement	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Control Change Evaluation
No. 2	Control Change Evaluation	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Institutional Incident Knowledge Management
No. 3	Institutional Incident Knowledge Management	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Management Improvement
No. 4	Business Resilience Improvement Support	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Institutional Incident Knowledge Management
No. 5	Incident Management Improvement	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Business Resilience Improvement Support
No. 6	Business Resilience Improvement Support	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Control Change Evaluation

Pairwise Comparison Set: Incident Handling Documentation Requirements

		Importance									Importance								
No. 1	Decision Making	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Nature
No. 2	Response Actions	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Decision Making
No. 3	Incident Nature	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Response Actions
No. 4	Response Plans	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Incident Nature
No. 5	Decision Making	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Response Plans
No. 6	Response Plans	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Response Actions

Pairwise Comparison Set: Visualization Usability Requirements

		Importance									Importance								
No. 1	Information Relevance	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Accessible
No. 2	Functional Relevance	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Convenience
No. 3	Information Relevance	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Functional Relevance
No. 4	Functional Relevance	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Accessible
No. 5	Accessible	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Convenience
No. 6	Convenience	9	8	7	6	5	4	3	2	*1*	2	3	4	5	6	7	8	9	Information Relevance

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Figure F.9: Ranking Instructions - Page 9

APPENDIX G. ANALYTICAL HIERARCHICAL PROCESS ANALYSIS RESULTS

This appendix contains averaged prioritization scores for the three leader roles, as well as the composite ranking across all five contributing group members. The Kano expectation assignment is noted above each table. Only design requirements of the same Kano expectation are in the same table. The AHP weights are sorted in ascending order. The last table contains the top five design requirements per their weights by leader role.

Table G.1: AHP Prioritization Results - **Expected** Kano Expectation

Incident Coordinator		**IT Leader**		**Business Leader**		**Overall**	
Requirement	Weight	Requirement	Weight	Requirement	Weight	Requirement	Weight
Direct Incident Cost	0.00385	Report	0.00545	Institutional Incident Knowledge Management	0.00387	Incident Nature	0.00886
Direct Incident Cost Risk	0.00388	Compliance Concerns	0.00591	Interactive External Entities	0.00563	Institutional Incident Knowledge Management	0.00953
Business Resilience Improvement Support	0.00491	Institutional Incident Knowledge Management	0.00686	Passive Non-Core Actors	0.00563	Passive Non-Core Actors	0.01006
Change Control Evaluation	0.00518	Policy and Guidelines	0.00773	Extent	0.00607	Report	0.01038
Incident Nature	0.00639	Interactive External Entities	0.00793	Incident Nature	0.00809	Direct Incident Cost Risk	0.01053
Extent	0.00656	Passive Non-Core Actors	0.00921	Time	0.00833	Interactive External Entities	0.01056

Table G.2: AHP Prioritization Results - **Expected** Kano Expectation (contd.)

Incident Coordinator		**IT Leader**		**Business Leader**		**Overall**	
Requirement	Weight	Requirement	Weight	Requirement	Weight	Requirement	Weight
Accessible	0.00813	Response Plans	0.01032	Response Plans	0.00839	Extent	0.01093
Convenience	0.00824	Incident Nature	0.01032	Change Control Evaluation	0.00872	Policy and Guidelines	0.01116
Out-of-Band Notification	0.00870	Time	0.01469	Projection	0.00924	Business Resilience Improvement Support	0.01132
Time	0.00936	Convenience	0.01471	Convenience	0.00971	Time	0.01160
Report	0.01037	Uncertainty Support	0.01514	Decision Making	0.01094	Convenience	0.01203
Policy and Guidelines	0.01179	Direct Incident Cost Risk	0.01748	Progression	0.01107	Change Control Evaluation	0.01251

Table G.3: AHP Prioritization Results - **Normal** Kano Expectation

Incident Coordinator		**IT Leader**		**Business Leader**		**Overall**	
Requirement	Weight	Requirement	Weight	Requirement	Weight	Requirement	Weight
Projection	0.01214	Interactive Internal Users	0.01813	Business Resilience Improvement Support	0.01125	Response Plans	0.01253
Passive Non-Core Actors	0.01308	Business Resilience Improvement Support	0.01908	Incident Management Improvement	0.01343	Direct Incident Cost	0.01293
Urgency	0.01528	Progression	0.01939	Policy and Guidelines	0.01490	Accessible	0.01544
Response Plans	0.01573	Extent	0.01991	Uncertainty Support	0.01518	Compliance Concerns	0.01664
Institutional Incident Knowledge Management	0.01588	Information Relevance	0.02064	Compliance Concerns	0.01559	Decision Making	0.01910

Table G.4: AHP Prioritization Results - **Normal** Kano Expectation (contd.)

Incident Coordinator		**IT Leader**		**Business Leader**		**Overall**	
Requirement	Weight	Requirement	Weight	Requirement	Weight	Requirement	Weight
Incident Management Improvement	0.01643	Decision Making	0.02065	Accessible	0.01635	Projection	0.01925
Interactive External Entities	0.01645	Response Actions	0.02065	Response Actions	0.01780	Urgency	0.01943
Decision Making	0.01996	Urgency	0.02130	Urgency	0.01807	Out-of-Band Notification	0.02158
Judgment/ Decision Task Awareness	0.02172	Accessible	0.02203	Direct Incident Cost Risk	0.01877	Response Actions	0.02203
Information Relevance	0.02245	Status	0.02299	Functional Relevance	0.01877	Incident Management Improvement	0.02430
Response Actions	0.02284	Direct Incident Cost	0.02536	Response Resource Tasking	0.02194	Progression	0.02514
Response Resource Acquisition	0.02451	Functional Relevance	0.02613	Direct Incident Cost	0.02720	Information Relevance	0.02516

Table G.5: AHP Prioritization Results - **Exciting** Kano Expectation

Incident Coordinator		**IT Leader**		**Business Leader**		**Overall**	
Requirement	Weight	Requirement	Weight	Requirement	Weight	Requirement	Weight
Response Role Management	0.03070	Change Control Evaluation	0.02759	Response Resource Acquisition	0.02842	Uncertainty Support	0.02526
Incident Plan Support	0.03145	Response Role Management	0.02930	Report	0.02964	Functional Relevance	0.03342
Compliance Concerns	0.04042	Incident Management Improvement	0.03509	Judgment/ Decision Task Awareness	0.03222	Interactive Internal Users	0.03366
Progression	0.04355	Projection	0.03576	Information Relevance	0.03394	Incident Plan Support	0.03723
Incident & Response Judgment/ Decision Escalation	0.04399	Out-of-Band Notification	0.03619	Out-of-Band Notification	0.03444	Judgment/ Decision Task Awareness	0.03753
Uncertainty Support	0.04451	Incident Plan Support	0.03646	Interactive Internal Users	0.03533	Response Role Management	0.03786
Status	0.04889	Timeline and Dependency Awareness	0.04112	Incident Plan Support	0.03699	Response Resource Acquisition	0.04221

Table G.6: AHP Prioritization Results - **Exciting** Kano Expectation (contd.)

Incident Coordinator		**IT Leader**		**Business Leader**		**Overall**	
Requirement	Weight	Requirement	Weight	Requirement	Weight	Requirement	Weight
Functional Relevance	0.04991	Information support	0.05171	Information support	0.04621	Status	0.04370
Interactive Internal Users	0.05478	Judgment/ Decision Task Awareness	0.05590	Response Role Management	0.05224	Response Resource Tasking	0.06035
Response Resource Tasking	0.05609	Incident & Response Judgment/ Decision Escalation	0.05877	Timeline and Dependency Awareness	0.07808	Incident & Response Judgment/ Decision Escalation	0.06656
Timeline and Dependency Awareness	0.07685	Response Resource Acquisition	0.06427	Intra Core	0.08324	Timeline and Dependency Awareness	0.06719
Intra Core	0.08168	Intra Core	0.06734	Status	0.09921	Information support	0.07055
Information support	0.09337	Response Resource Tasking	0.07849	Incident & Response Judgment/ Decision Escalation	0.10511	Intra Core	0.08147

APPENDIX H. REQUIREMENTS RANKING COMPARISON VISUALS

As mentioned in the discussion of Stage O (Section 3.2.13), the 70% ranking was chosen to determine which requirements to emphasize. The first figure (Figure H.1) shows both requirement levels. In the foreground are the nine highest-level requirements. The various pie charts indicate the percentages of related second-level requirements present in a particular region. The pie wedges have various colors in order to indicate how many second-level requirements were descendants of a particular high-level requirement. The darkest color is associated with a high-level requirement having three second-level requirements. The next darkest color wedge indicates that the high-level requirement has four second-level requirements. The lightest color wedge indicates the presence of five second-level requirements for the associated high-level requirement. A bolded high-level requirement label indicates that all related second-level requirements met the ranking threshold, and that these second-level requirements are located within one of the other leader role regions.

The second figure (Figure H.2) is focused on the second-level requirements. Due to the density of placed objects, it was necessary to reference the second-level requirements by their number-letter code. The number following the requirements label is the percentage threshold relevant to the object's placement within the figure. Second-level requirement placement has been done for the 65%, 70%, 75% and 80% thresholds. As a visual aid, requirement objects highlighted in yellow are those associated with the 70% ranking threshold. The bolded labels indicate threshold agreement with the "Overall Leader"

ranking computed by averaging all group member ranking inputs for a requirement. For example, the second-level requirement 4.A (Response Resource Acquisition) meets the 65% threshold for the IT Leader as well as the 65% threshold of the Overall Leader after combining all ranking input for that requirement. The rays are intended to point out changes in agreement as the threshold increases. Where space permitted, if a requirement did not change in agreement, then the object for that threshold was placed horizontally from the previous instance of that requirement. The border around an object indicates whether the requirement was visible or directly apparent to the user. A user may find some requirements that influence software characteristics (i.e. borderless requirement objects) difficult to identify because they are either diffused, emergent, foundational, or systems interfaces that were not user-accessible through the visualization interface.

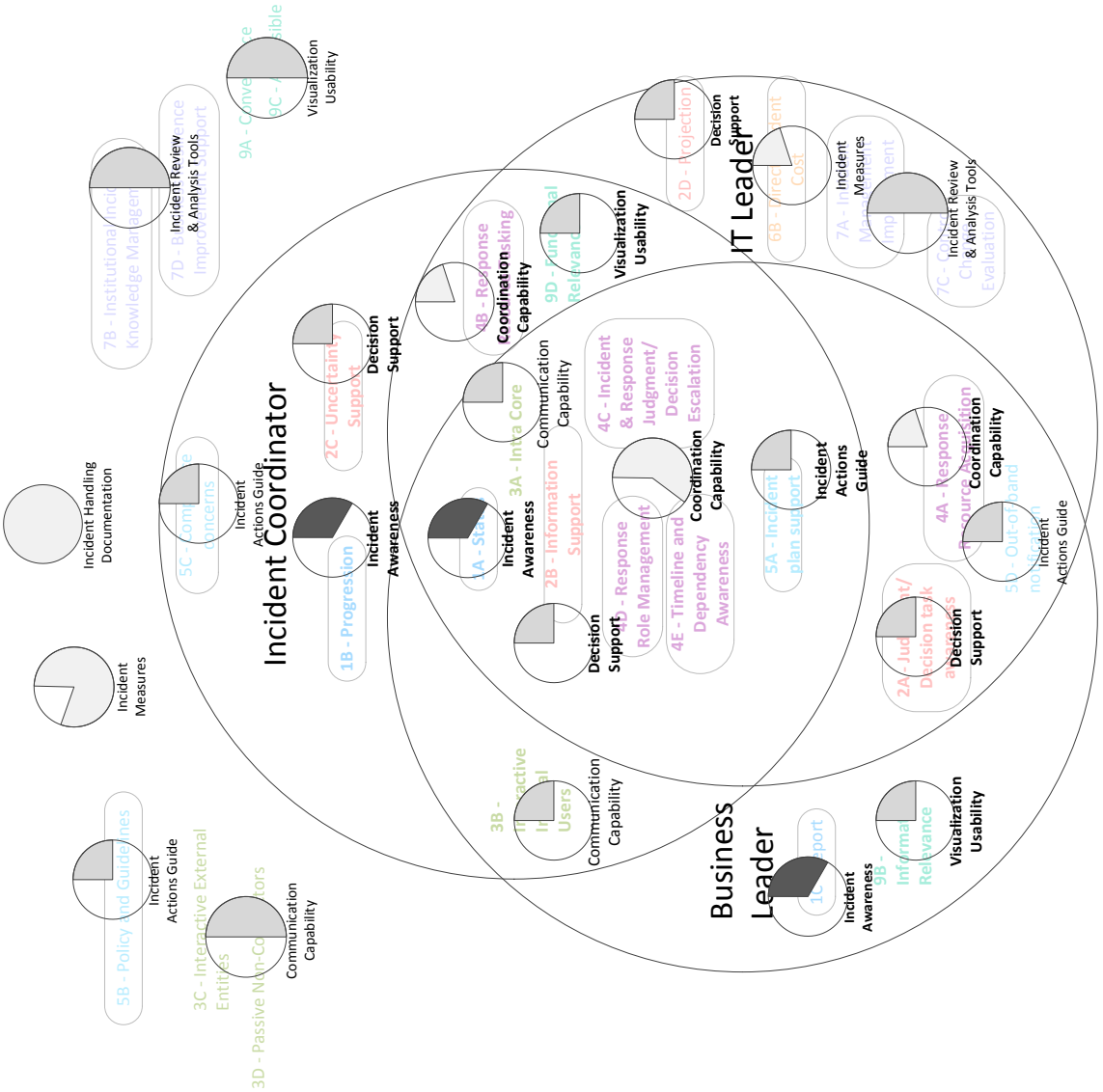


Figure H.1: High-Level and Design-Level Requirements at 70% Threshold

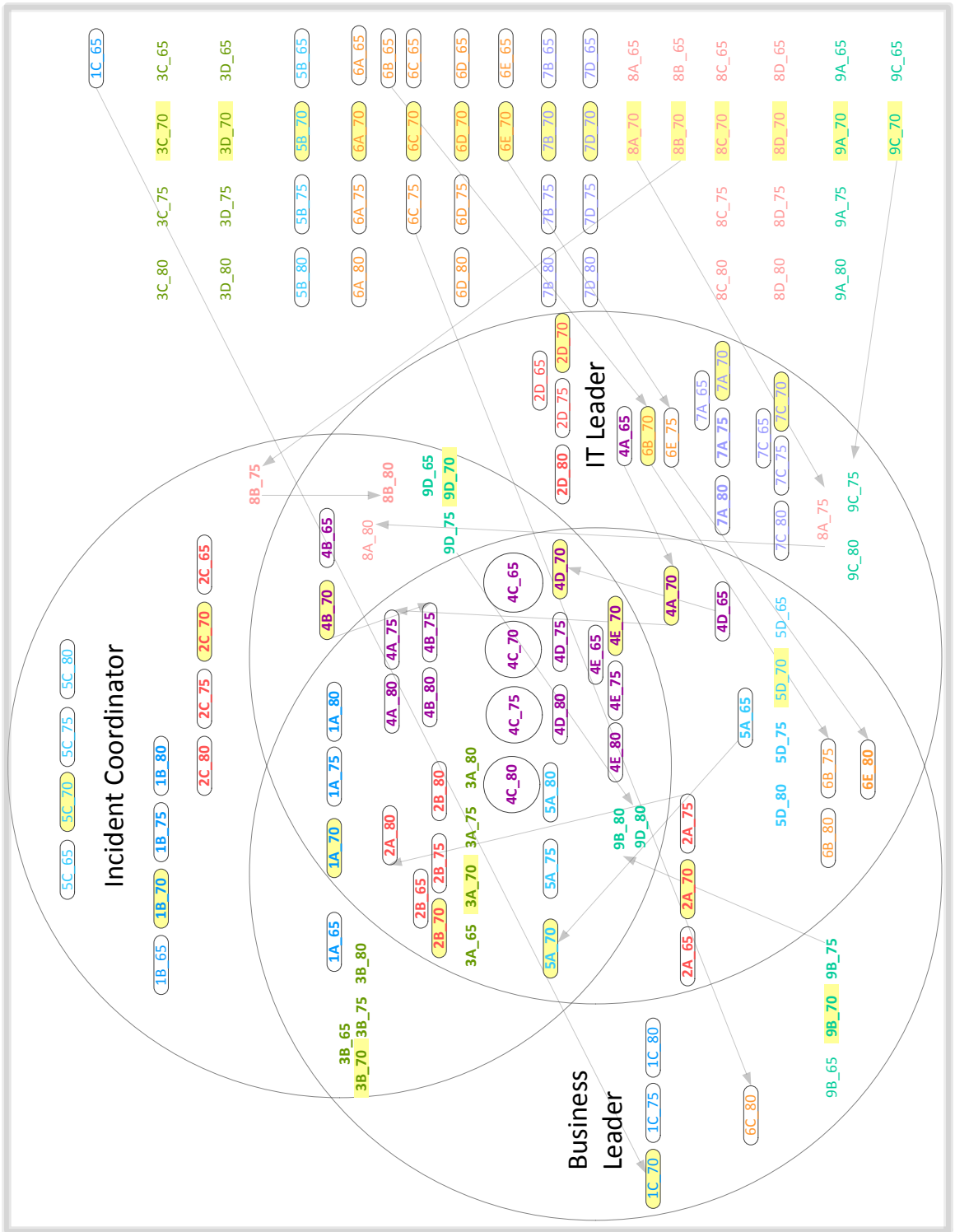


Figure H.2: Progression of Preference over Thresholds

APPENDIX I. REQUIREMENT PRIORITY INTERPRETATION

This appendix contains the requirements handling plan that resulted from the requirements prioritization interpretation discussed in Stage N (Section 3.2.12).

Notation Explanations

- All indicates that the requirement fell within the specified cutoff for the Overall user group.
- The two-letter abbreviations in the Inclusion Status column represent leader roles:
  - "IT" is short for "IT Leader"
  - "IC" is short for "Incident Coordinator"
  - "BL"is short for "Business Leader"
- Bolded requirement labels indicate they are visible requirements.
- The Comment field contains the phrase "Non-visible context requirement." This phrase means that the requirement would not manifest itself as a specific feature or screen element, but would be relevant to the use-case and content present during the evaluation.

Table I.1: Requirements Prioritization Interpretation

High-Level Requirement	**Design Requirement**	**Inclusion Status**	**Comment**
Incident Handling Awareness	**1.A Status**	All with equal emphasis by role	Within 70% preference threshold
	1.B Progression	All with IC emphasis	Within 70% preference threshold
	1.C Report	BL	Within 70% preference threshold
Decision Support	**2.A Judgment/ Decision Task Awareness**	All with BL & IT emphases	Within 70% preference threshold
	2.B Information Support	All with equal emphasis by role	Within 70% preference threshold
	2.C Uncertainty Support	All with IC emphasis	Within 70% preference threshold
	2.D Projection	IT	Within 70% preference threshold
Communication Capability	3.A Intra Core	All	Within 70% preference threshold. Non-visible context requirement
	3.B Interactive Internal Users	All with IC & BL emphasis	Within 70% preference threshold. Non-visible context requirement
	3.C Interactive External Entities	OUT	
	3.D Passive Non-Core Actors	OUT	

Table I.2: Requirements Prioritization Interpretation (contd.)

High-Level Requirement	**Design Requirement**	**Inclusion Status**	**Comment**
Coordination Capability	**4.A Response Resource Acquisition**	All with BL & IT emphases	Within 70% preference threshold
	4.B Response Resource Tasking	All with IC & IT emphases	Within 70% preference threshold
	4.C Incident & Response Judgment/ Decision Escalation	All with equal emphasis by role	Within 70% preference threshold
	4.D Response Role Management	All with equal emphasis by role	Within 70% preference threshold
	4.E Timeline and Dependency Awareness	All with equal emphasis by role	Within 70% preference threshold
Incident Actions Guide	**5.A Incident Plan Support**	All with equal emphasis by role	Within 70% preference threshold
	5.B Policy and Guidelines	OUT	
	5.C Compliance Concerns	IC	Within 70% preference threshold. Not clear if lack of preference weight is indicative of reality for other roles.
	5.D Out-of-band notification	BL & IT	Within 70% preference threshold. Non-visible context requirement

Table I.3: Requirements Prioritization Interpretation (contd.)

High-Level Requirement	**Design Requirement**	**Inclusion Status**	**Comment**
Incident Measures	**6.A Time**	All with equal emphasis by role	Dependency & necessary requirement
	6.B Direct Incident Cost	All with emphasis with IT	Dependency & necessary requirement
	6.C Direct Incident Cost Risk	All with equal emphasis by role	Dependency & necessary requirement
	6.D Extent	All with equal emphasis by role	Dependency & necessary requirement
	6.E Urgency	All with equal emphasis by role	Dependency & necessary requirement. Steadily gains priority with higher cutoffs

Table I.4: Requirements Prioritization Interpretation (contd.)

High-Level Requirement	**Design Requirement**	**Inclusion Status**	**Comment**
Incident Review & Analysis Tools	**7.A Incident Management Improvement**	IT	Within 70% preference threshold. Unclear whether evaluation constraints will allow an "after-action" scenario extension
	7.B Institutional Incident Knowledge Management	OUT	
"	**7.C Control Change Evaluation**	IT	Within 70% preference threshold. Unclear whether evaluation constraints will allow an "after-action" scenario extension
	7.D Business Resilience Improvement Support	OUT	
Incident Handling Documentation	8.A Decision Making	All	Non-visible context requirement & dependency for 7.A and 7.C
	8.B Response Actions	All	Non-visible context requirement & dependency for 7.A and 7.C

Table I.5: Requirements Prioritization Interpretation (contd.)

High-Level Requirement	**Design Requirement**	**Inclusion Status**	**Comment**
Incident Handling Documentation	8.C Response Plans	All	Non-visible context requirement & dependency for 7.A and 7.C
	8.D Incident Nature	All	Non-visible context requirement & dependency for 7.A and 7.C
Visualization Usability	9.A Convenience	All with equal emphasis by role	Non-visible context requirement & necessary requirement
	9.B Information Relevance	All with emphasis with BL	Within 70% preference threshold. System behavior requirement
	9.C Accessible	All with equal emphasis by role	Non-visible context requirement & necessary requirement
	9.D Functional Relevance	All with emphasis with IC & IT	Within 70% preference threshold. System behavior requirement

APPENDIX J. HIGH-LEVEL DESIGN OF EVALUATION ACTIVITY AND SCREEN SEQUENCING

Figure J.1 describes one possible sequence of tasks and evaluation objectives considered for the allotted 20-minute period. This task sequencing was used to ensure that an evaluator experienced the features related to the "highly preferred" requirements in the requirement prioritization that took place in Stage N (Section 3.2.12). This timeline approach helped with determining the number, complexity, sequencing and objectives of the evaluation tasks. Although the objective of this research was to introduce general visualization concepts for IT incident management, it was necessary that the tangible implementation of the research findings (i.e. the prototype) be developed with strict focus on the actual validation use-case.

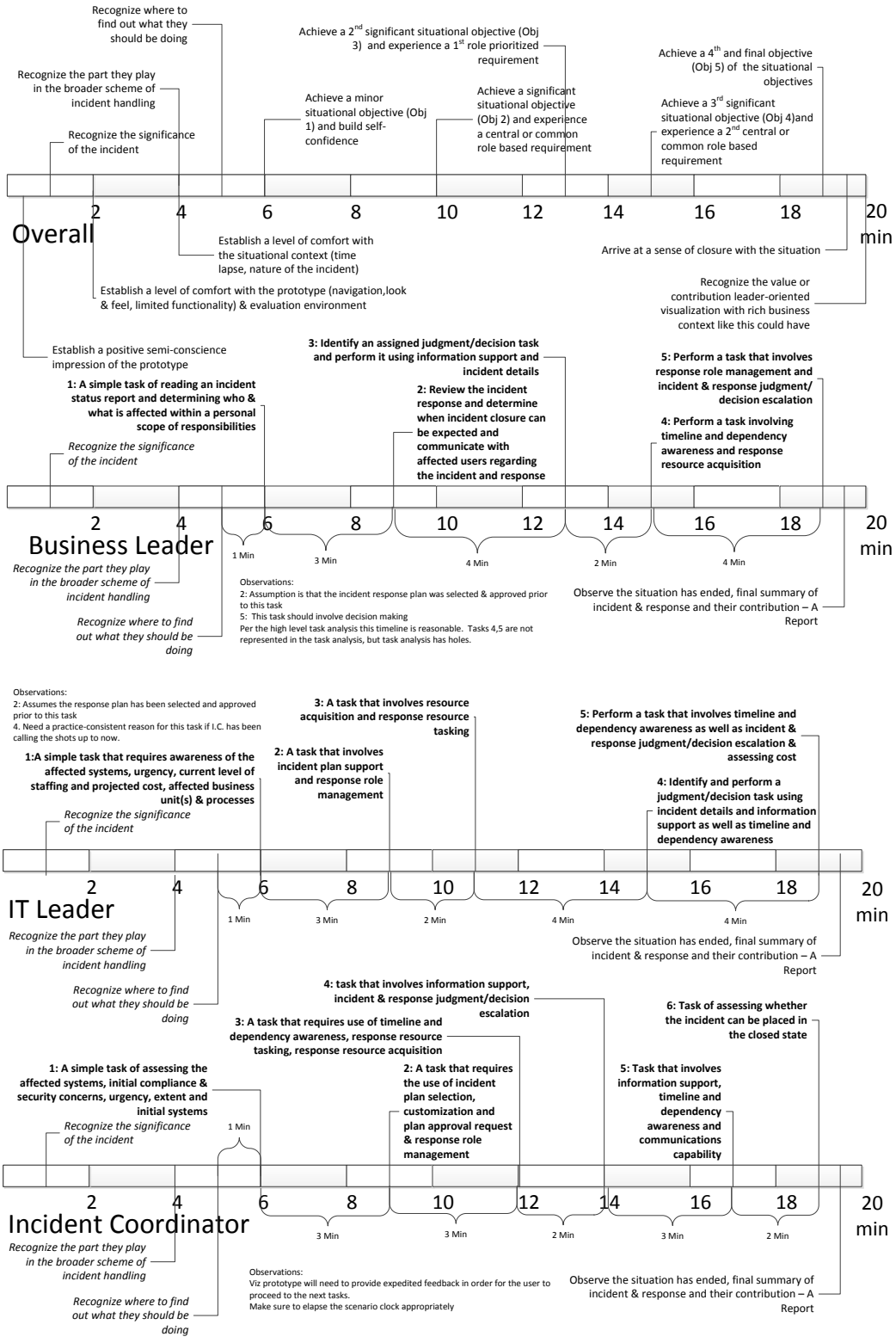
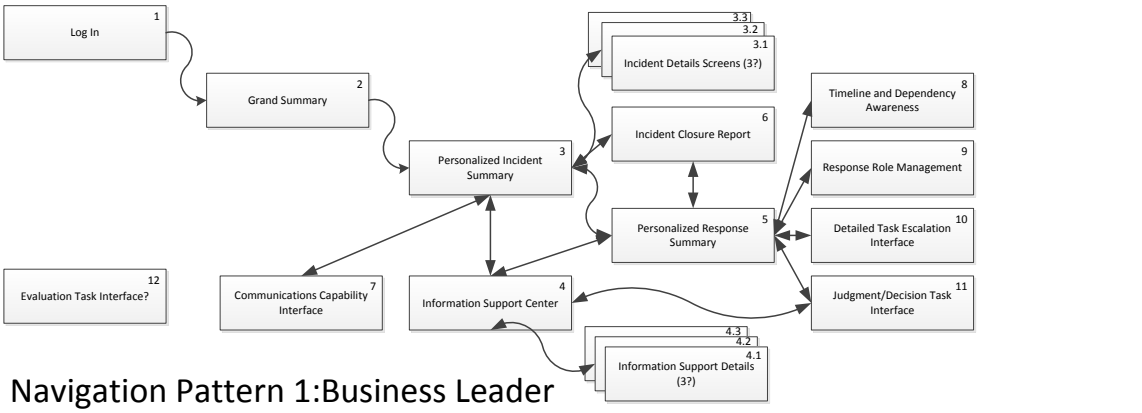
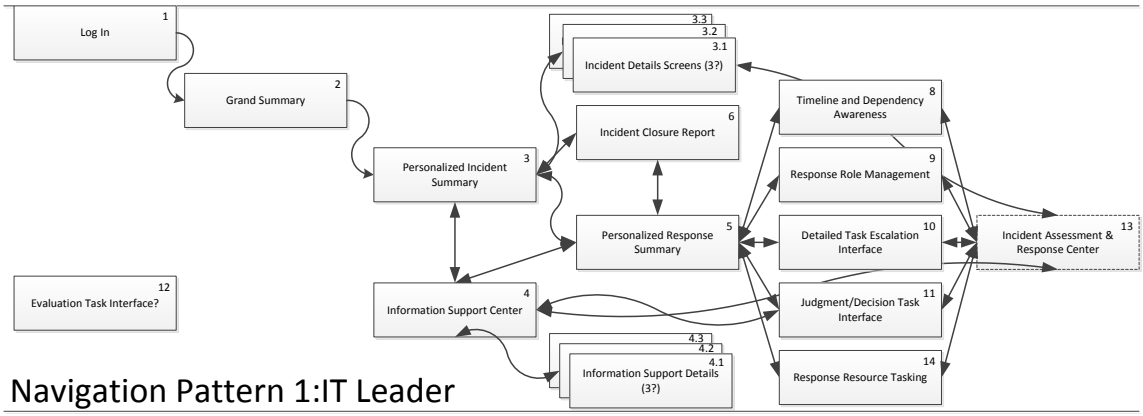


Figure J.1: Evaluation Task Sequencing Timeline

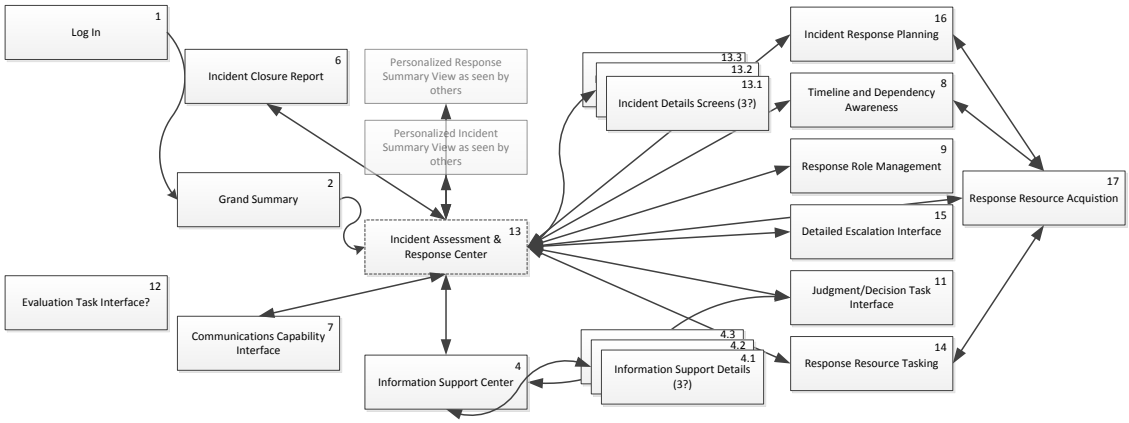
Figure J.2 was one of two screen patterns developed for the high-level design and was presented to the Study Group members. The other pattern was a slight modification made possible by consolidating screens such as the "Personalized Incident Summary" and "Personalized Response Summary." The number in the top right corner was the screen's numeric label. This allowed for easier tracking between the hand-drawn sketches and this overall navigation blueprint. The numbers were unique across all three patterns. Cases in which the screens' labels across patterns are the same indicate that a particular screen was in large part being reused. In some cases, role-specific presentations were suggested as substitute elements within a screen. The dim screen objects within the Incident Coordinator pattern were presented for the purpose of completeness, but there was no intention to implement this navigation sub-pattern for the evaluation.



Navigation Pattern 1:Business Leader



Navigation Pattern 1:IT Leader



Navigation Pattern 1:Incident Coordinator

Figure J.2: Possible Screen Flow

APPENDIX K. CALL FOR PARTICIPATION

The document below was sent through professional mailing lists as well as to people interested in supporting the research effort. The actual locations have been stripped from the document to ensure the privacy of both the hosts and the participants. However, the locations listed were in the Des Moines, Iowa metropolitan area.

Come Evaluate IT Visualization Research

The Information Assurance Center (IAC) of Iowa State University is pleased to announce the opportunity to learn about and evaluate research in visualization of IT incidents. This public evaluation is conducted as part of a research project being performed by the IAC.

For this research, an IT incident is an event that affects the integrity, confidentiality and/or availability of information and information systems. These events have sufficient impact or risk that they merit collaboration of leadership personnel beyond the workgroup.

A research team of the IAC has been developing an IT Incident Visualization System in cooperation with IT professionals in the Greater Des Moines metropolitan area. This work is approaching a key milestone at which a prototype needs to be evaluated by a broader IT professional audience before proceeding to the next stage of research and development.

IAC is looking for IT professionals who are IT leaders. Personnel management experience is not necessary. A qualified person should have direct IT incident response involvement for at least one IT incident. Finally, a qualified person will have experience with evaluating business risks associated with an IT incident.

Multiple evaluation events will be conducted at various locations in the Greater Des Moines metropolitan area. Each event will have limited number of seats available. Please connect to http://www.iac.iastate.edu/content/outreach/ipe to obtain a free ticket. If you have problems with online registration or questions regarding registration please write to iacoutreach@iastate.edu. The only cost is your time and energy.

An evaluator will attend one evaluation event that will last approximately 75 minutes.

All aspects of these evaluation events are absolutely voluntary. You may withdraw at anytime or refuse to answer any question. Data collected from your participation will be anonymous.

The online registration will collect identifiable information for facility security purposes. Contact information will allow us to provide you with event updates. Registration records will not be used beyond these purposes.

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Figure K.1: Call for Participation - Page 1

Below, you will find the start times and locations for these events. Multiple events have been scheduled at each location. Additional times and locations may be scheduled between October 22 and November 16, 2012 if interest merits. Please check with the iacoutreach@iastate.edu for potential additions to the schedule.

Location	Date and Room Information	Start Times
Location 1	Wednesday, October 24, 2012 Room: Conference Center 4	10:00 AM 1:00 PM
Location 2	Thursday, November 1, 2012 Room: A Level, Conference Room 7	10:00 AM 1:00 PM
Location 3	Thursday, November 8, 2012 Room: 3041	11:00 AM 1:00 PM

Any questions regarding these events should be directed to:

Mark Tannian
mtannian@iastate.edu
515.494.1014

Doug Jacobson
dougj@iastate.edu
515.294.8307

Thank you for you time and consideration. We look forward to seeing you at one of these events.

Dr. Doug Jacobson
Information Assurance Center, Director
Iowa State University

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Figure K.2: Call for Participation - Page 2

APPENDIX L. EVALUATION ENVIRONMENT STATE MACHINES

Two state machines were developed to facilitate the "Choose Your Own Adventure" evaluation experience. One state machine was developed to accommodate changes to the narrative content as task choices were made. The second state machine gave the evaluator flexibility to pick an evaluation task to perform.

The labeling within the state machine diagrams consists of a prefix for the state machine to which the state belonged, followed by either a number or number-letter combination. The significance of the number portion of the label is common across the two state machines and represents the evaluation task within the sequence; the letters were a means of uniquely labeling the alternatives.

Evaluation task 2 provided the evaluator an option to pick a task to perform. The task state machine branched out to accommodate that task selection when the evaluator transitioned to task 3. As the objective was to ensure that each evaluator experienced a similar set of task experiences, task 3 was a means to normalize the experience across evaluators.

Each evaluation task choice option was given a label to facilitate the narrative state transitions. One can see that not all choices resulted in a relative divergence in narrative state. Each narrative state consisted of numerous IT incident indicators and response status attributes. The state machine was kept relatively simple in order to avoid narrative content design complexity and complications. Each letter assigned in the number-letter pairs within the narrative state machine tracked with the label assigned to each choice

in the software. The label “A” was assigned to a choice considered the best choice. The label “B” was assigned to a choice considered satisfactory. The label “C” was assigned to the worst choice among the three presented in tasks 1 – 5.

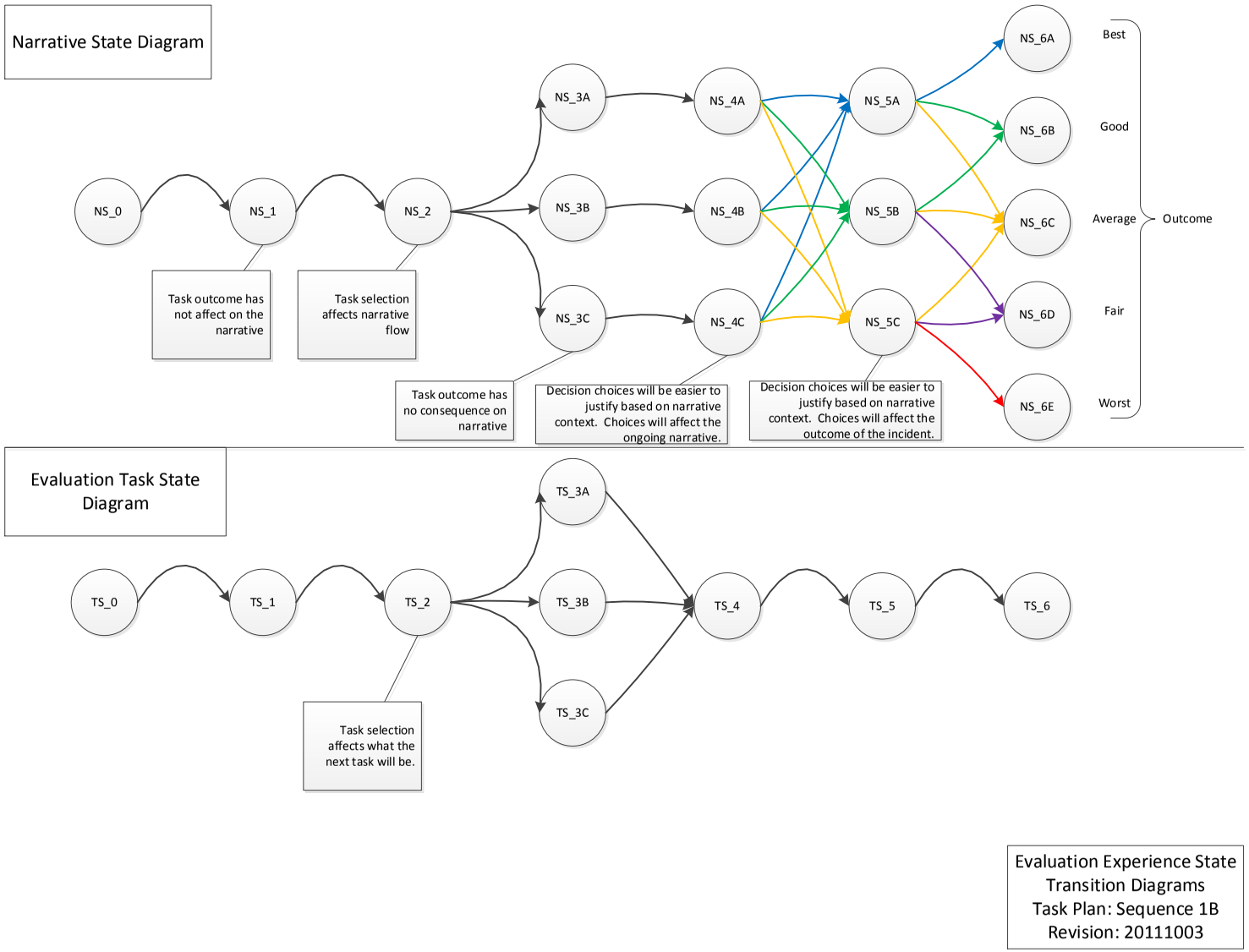

Figure L.1: Evaluation Environment State Machines

APPENDIX M. EVALUATION TASKS

In the table below, the "Task Descriptions" and "Task Choices" listed are those the evaluators worked with during the evaluation events. The text surrounded by square brackets within the Task Description field is a placeholder for the actual button the user could select to set the prototype to the screen indicated by the text.

The "Quality Assessment" listed next to each task choice is the assessed quality of the decision used to influence the narrative outcome of the IT incident. The activity log showed these values in the form of "Choice_X," where"X" is a placeholder for the assessed quality. This same convention was used to indicate the task selected in the first part of Task 2, but in this case the letters "A," "B" or "C"simply denote the task selected and do not indicate an assessed quality for the task chosen. The order in which the task choices have been listed is consistent with the choice order presented to the evaluators.

Table M.1: Evaluation Tasks

Task ID	**Task Description**	**Task Choices**
1	Orientation: You are starting with the [Grand Summary] visible. You will see a number of incidents are active. As mentioned in the briefing, an incident has been opened for systems that your team is responsible for maintaining. Instructions: Select the incident to which you have been assigned and review the incident details on the [Incident Summary]. Select one of Task Choices (just to the right) after finding the following incident details: A) the primary affected system, B) the name of the Incident Coordinator, C) the current cumulative direct costs, D) urgency level, E) current state of the incident.	A) OrderPortal1, B) Matthew Rich, C) \$15,179, D) 3, E) Planning Quality Assessment = B A) OrderPortal1, B) Matthew Rich, C) \$7,621, D) 3, E) Assessment Quality Assessment = A A) IAAuth1, B) Kevin Nelson, C) \$7,621, D) 3, E) Assessment Quality Assessment = C

Table M.2: Evaluation Tasks (contd.)

Task ID	**Task Description**	**Task Choices**
2	Orientation: As you can see on [Response Summary] , the urgency for this incident has changed. The response plan for this incident has several response tasks assigned to you. There is a collection of tasks of concern (1501, 1502, 1503). These tasks are related to facilitating response efforts during the current Assessment phase. Your fictional character has been addressing 1501, 1502 and 1503 since you logged in. You identified 3 possible actions to take. This evaluation task starts with you selecting one of those actions. There will be no negative consequence for picking any of these actions. Evaluation Task 3 will cover the two actions you did not select here. Instructions: Select one of three pending actions associated with tasks 1501 and 1503 in Task Choices (just to the right). This Task Description window will update after you select the response action to perform.	Approve resource request Logging Label = A Request an additional resource Logging Label = B Manage task completion tardiness Logging Label = C

Table M.3: Evaluation Tasks (contd.)

Task ID	Task Description	Task Choices
2A	Action Selected: Approve resource request Orientation: Besides you, the Incident Coordinator is working on expediting response efforts. Recent cost and productivity loss containment policy has introduced the need for leadership to approve resources assigned to incident response. A resource acquisition request, RAR-0015, has been opened for an additional system administrator from your team. Approve the request by assigning the person you feel is the best choice for response need mentioned in RAR-0015. Instructions: You can see the mechanics of request approval on the Approve sub-screen of [Response Resource Acquisition] . Completing this Evaluation Task is a matter of selecting a name from the list in Task Choices (just to your right). You might want to do a "By Skill" lookup of employees in the Human Resources section of the [Information Support Center] to help make your choice.	Steve Roy with restrictions on availability Quality Assessment = A Chris Tuttle with restrictions on availability Quality Assessment = B Leo Campbell with restrictions on availability Quality Assessment = C

Table M.4: Evaluation Tasks (contd.)

Task ID	Task Description	Task Choices
2B	Action Selected: Request an additional resource Orientation: Several upcoming tasks (1240, 1320, 1420) have not been staffed. Currently there is no one on the team who can perform these tasks due to the skills required. This Evaluation Task is matter of identifying the response role this additional resource would likely have to satisfy the needs of these tasks. Ideally you could request this resource to be available throughout the incident response timeframe. However, if you had to limit their involvement what availability timeframe would you specify? The resourcing issues associated with 1240, 1320 and 1420 can be seen on [Timeline & Dependency Awareness] and a bit differently on [Response Summary] Graphical View sub-screen or on [Response Resource Tasking]. Instructions: In preparation for making a resource request, select from the Task Choices (just to the right) one of the possible pairs of needed role and availability time frame for the missing resource you are requesting. Beyond the screens previously mentioned, you might find a "By Skills" lookup in the Human Resources section of the [Information Support Center] screen helpful to see how the needed skills align with skill groups.	Server Administrator available from 16:00 - 19:00 today Quality Assessment = C Business Leader available from 16:00 - 19:00 today Quality Assessment = B Business Analyst available from 16:00 - 20:00 today Quality Assessment = A

Table M.5: Evaluation Tasks (contd.)

Task ID	**Task Description**	**Task Choices**
2C	Action Selected: Manage task completion tardiness Orientation: Although task ID 1110 is not in the critical path, it clearly is important to resolving this incident. If this task delays much longer it will be in the critical path. An additional resource billet has been opened for skills not previously allocated to this task. This billet was opened with hopes these skills will pick up the pace on completing 1110. This Evaluation Task is for you to assign an appropriate acquired resource to the task. Instructions: You can see on [Timeline & Dependency Awareness] or on the [Response Resource Tasking] screen that the task ID 1110 is likely to be late in completion. Make your assignment by selecting a person from the Task Choices list (just to the right). Note: A "By Skill" search in the Human Resources section of the [Information Support Center] and [Response Role Management] screen may be helpful in choosing from the 3 people listed.	John Chang Quality Assessment = A Evaluation User (That's You) Quality Assessment = C Kevin Nelson Quality Assessment = B

Table M.6: Evaluation Tasks (contd.)

Task ID	Task Description	Task Choices
3A	Orientation: No definitive cause for the problems related to OrderPortal1 has been found. Troubles are being reported on OrderMgmt1. Response procedure requires that secondary systems be inspected. IAAuth1 is a crucial secondary system responsible for authentication and authorization. Instructions: This task has 2 parts. Part 1: When you look at the response plan in the Graphical View sub-screen of the [Response Summary], a recently added task of ID 1130: "Investigate IAAuth1" requires resources. Click on "Initiate Request" button in Task Choices (just to the right) and watch a request process tutorial. Part 2: While that request is being processed by a different person, go to [Response Resource Tasking] to see who you would direct to function as an available network admin. to look at IAAuth1's network infrastructure for task ID 1130. Pick a person listed in Part 2 (just to the right) you think will meet this need for task 1130.	Part 1: [Initiate Request] Part 2: Zhao Shi Quality Assessment = A Evaluation User (That's You) Quality Assessment = C Kevin Nelson Quality Assessment = B

Table M.7: Evaluation Tasks (contd.)

Task ID	Task Description	Task Choices
3B	Orientation: With no definitive cause for the problems related to OrderPortal1 identified and troubles being reported on OrderMgmt1, the response policy requires that secondary systems be inspected. IAAuth1 is a crucial secondary system responsible for authentication and authorization. IAAuth1 is based on CA SiteMinder. Zhao Shi has been approved to inspect the authentication and entitlement service. Instructions: This task has 2 parts. Part 1: Since Zhao Shi is a new member of the team, a response role needs to be assigned. One way to determine the role that should be assigned is to go to [Response Role Management] Go to the "Manage Roles" sub-screen to see the role management interface. Select Response Member role category and hover over the three roles mentioned in Task Choices (just to the right). Decide what role to assign and indicate your choice in Task Choices Part 1. Part 2: Now that Zhao has a role. You need to assign Zhao the task of executing the inspection of IAAuth1 by going to [Response Resource Tasking]. Identify the appropriate task ID and indicate your choice of task ID in Task Choices Part 2 (just to the right).	Part 1: Application Security Controls Specialist Quality Assessment = A Customer Applications Developer Quality Assessment = C Network Administrator Quality Assessment = B Part 2: Task ID 1110 Quality Assessment = C Task ID 1311 Quality Assessment = B Task ID 1130 Quality Assessment = A

Table M.8: Evaluation Tasks (contd.)

Task ID	Task Description	Task Choices
3C	Orientation: No definitive cause for the problems related to OrderPortal1 has been found. Troubles are being reported on OrderMgmt1. Response procedure requires that secondary systems be inspected. IAAuth1 is a crucial secondary system responsible for authentication and authorization. Instructions: This task has 2 parts. Part 1: Looking at the response plan in the Graphical View sub-screen of the [Response Summary], you will see a recently added task of ID 1130: "Investigate IAAuth1" requires resources. Click on "Initiate Request" button in Task Choices (just to the right) and watch a request process tutorial. Part 2: Your request has been instantly approved. Zhao Shi has been approved to inspect the authentication and entitlement services (IAAuth1) based on CA SiteMinder. Having just been approved, Zhao does not have a role assigned for this response effort. You need to assign him the role you feel is most appropriate given he is going to be assigned to task ID 1130 to investigate the CA SiteMinder implementation. In order to determine which role to assign Zhao, you may find looking at the Graphical View of the [Response Summary] useful. Another screen that can assist you is the [Response Resource Tasking] screen. If you were to actually manage Zhao's role assignment, you would go to the Manage Roles sub-screen of the [Response Resource Tasking] screen.	Part 1: [Initiate Request] Part 2: Customer Applications Developer Quality Assessment = C Network Administrator Quality Assessment = B Application Security Controls Specialist Quality Assessment = A

Table M.9: Evaluation Tasks (contd.)

Task ID	Task Description	Task Choices
4	Orientation: Response team members assigned to task ID 1130 have been working on isolating the issue within IAAuth1. After inspecting configuration files, operational statistics and log entries, the team feels it is necessary to restart the router module of the switch F-RTR-SEC0X. The ACL caches may be corrupted. The task of approving the timing of the restart is your decision. By going to the [Judgment & Decision Interface] screen you see the judgment & decision entry for task ID 1130. There are mechanisms that allow you to transfer this decision to someone else, but you are going to make the call. Instructions: Go to the [Judgment & Decision Interface] screen and pull up the entry for task ID 1130 to see the available details. Your decision options are listed in Task Choices (just to the right). The request as prepared essentially asks for an immediate restart. However, you can choose to approve a delayed restart. Part of the justification for your decision is the current urgency of the incident. You can see on the [Urgency Details] screen various contributing factors into the urgency calculation. The referenced change management record can be seen in the Change Management module of [Information Support] screen. [Note: In an actual incident management setting, the task relationships and resourcing challenges presented on [Timeline & Dependencies] screen may also contribute to your decision and related justification.	Immediate module restart after notice release. Further delay is unacceptable for the given urgency level. Urgency = 3 or 5 Quality Assessment = B Urgency = 7 Quality Assessment = A Provide immediate warning and restart in 1 hour. Urgency justifies minimal delay that is necessary for stakeholders to prepare for service loss of OrderPortal1 and OrderMgmt1. Urgency = 3 or 5 Quality Assessment = A Urgency = 7 Quality Assessment = B Provide immediate warning and restart at 20:00 CST (start of light system load period). Urgency does not justify a more immediate restart. OrderPortal1 and OrderMgmt1 users are struggling but there are valid transactions being completed. Quality Assessment = C Note: The assessed quality was narrative-sensitive. Depending on the urgency value for the state of the narrative, the assessed quality may have changed.

Table M.10: Evaluation Tasks (contd.)

Task ID	Task Description	Task Choices
5	Orientation: The router module (F-RTR-SEC0X) restart from the last Evaluation Task had little long term impact on the problem being experienced with OrderPortal1 and OrderMgmt1. Although the specific cause for IAAuth1's inconsistent behavior has not been pinned down, it is clear that OrderPortal1 and OrderMgmt1 performance has been negatively affected by their reliance on IAAuth1 for authentication and authorization. The Assessment phase is nearing the end. The incident scoping activities during the 1200 series tasks and judgments up to this point have pointed to no additional incident scope creep beyond the 3 systems already mentioned. It is time for the incident to be characterized in order to set the tone for the remainder of the incident. There are three characterizations of Operational, Security and Compliance. Each of which will affect the policies, procedures, personnel and communications that apply to this incident. Instructions: When looking at the [Judgment Decision Interface] screen and retrieving the judgment task 1781, you have been asked to participate in the process of characterizing this incident. This judgment is ultimately the IT Director's. The judgment task record you see on the [Judgment Decision Interface] screen shows the list of people contributing to the judgment. The information security lead has offered his opinion. It is now up to you to pass on your characterization of this incident. In Task Choice (just to the right), you will see 3 possible responses. Choose one and click on "Commit Choice."	Simply an operational incident. Someone applied or made an ill-advised configuration change within IAAuth1. Quality Assessment = A Could be a security incident. Someone may have rooted the Policy Server and is throttling authentication and authorization responses. Quality Assessment = C Contractual compliance issue. Customers have negotiated a quality of service for systems OrderPortal1 and OrderMgmt1. Quality Assessment = B

Table M.11: Evaluation Tasks (contd.)

Task ID	**Task Description**	**Task Choices**
5(contd.)	You may find helpful information on the [Incident Summary] and supporting detail screens. Task outcomes and related comments made by team members can be found in the Graphical View of the [Response Summary] and on the [Timeline Dependency] screens.	
6	Orientation: Incident time has now fast forwarded to the point where the incident has just been closed. The screen presented is an interim closure report generated from content collected throughout the incident. A final report drawing from incident responder insights would come out later. Instructions: Look over the incident closure report and compare it to the Task Choices (just to the right) pick one of 5 entries with the parameters that best fit the report you see: a) total direct costs, b) duration, c) the number of affected systems. Note: The options you see are all the possible incident outcomes that could have resulted from your evaluation choices. They are listed in descending from best possible outcome to worst.	a) \$60,039 b) 24 hours c) 3 systems Logging Label = A a)\$78,287 b) 32 hours c) 3 systems Logging Label = B a) \$87,411 b) 36 hours c) 3 systems Logging Label = C a) \$95,460 b) 40 hours c) 3 systems Logging Label = D a) \$105,659 b) 44 hours c) 3 systems Logging Label = E

APPENDIX N. RECONCILIATION OF ACTIVITIES

The field study methodology described in Chapter 3 used research activity terminology not consistent with the documentation submitted to the IRB for review and approval. Moreover, the quantity of activities does not align between this document and the IRB documentation. This was in large part due to hindsight. Greater clarity was achieved by looking back at what was accomplished as opposed to referring to previous planning terminology, thus providing more informative documentation.

Table N.1: Comparison of Activities

Chapter 3 Activities	IRB Proposal Activities	Comments
A. Define Problem and User Group	1. Define Problem and User Group	Chapter 3 and the IRB proposed activities align.
B. Understanding the Need	2. Understanding the Need/Verifying the Problem Exists	Chapter 3 and the IRB proposed activities align. Label for Chapter 3 is only simplified.
C. Analysis of Visualization Needs		This Chapter 3 activity was added to clarify the need for post-processing of "B."
D. Develop a Catalog of Needs		This Chapter 3 activity was added to clarify the additional post-processing needed for "B."
E. Prioritizing the Needs		This Chapter 3 activity was added as a followup activity with the Study Group. The variety and lack of overlap expressed in "B" necessitated a call for confirmation and prioritization.

Table N.2: Comparison of Activities (contd.)

Chapter 3 Activities	IRB Proposal Activities	Comments
F. Analysis of Need Priorities		This Chapter 3 activity was added to clarify the need for post-processing of the feedback elicited in "E."
G. Need/Task Selection	3. Select a Task from the Task Pool Collected for Prototyping / Preliminary Exam	Chapter 3 and the IRB proposed activities align. Label for Chapter 3 is only simplified.
H. Understanding Selected Task	4. Develop Deeper Understanding of Selected Tasks	Chapter 3 and the IRB proposed activities align. Label for Chapter 3 is only simplified.
	5. Identify Appropriate Theoretical Foundations from Relevant Fields	This IRB proposed activity is not referenced in Chapter 3, since this academic activity is somewhat obvious and had no distinct endpoint.
I. Analysis of Task Exploration		This Chapter 3 activity was added to clarify the need for this type of post-processing of H.
J. Identify Actors & Dynamics		This Chapter 3 activity was added to clarify the need for this type of post-processing of H.
K. Identify Requirements		This Chapter 3 activity was added to clarify the need for this type of post-processing of H.

Table N.3: Comparison of Activities (contd.)

Chapter 3 Activities	IRB Proposal Activities	Comments
L. Review & Influence Requirements & Understanding		This followup activity was necessary to verify that what was learned from the previous analysis steps was reasonable and relevant across the Study Group. Requirements development was necessary for upcoming design activities. The requirements were based on the synthesis of literature and task understanding. It was necessary for the Study Group to agree to requirement definitions and their merit, as well as to influence their composition.
N. Prioritize Requirements		This followup activity was necessary for upcoming design activities. It is impossible to give each requirement equal weight in the design.
O. Interpret Requirement Priorities		This Chapter 3 activity was added to clarify the need for this type of post-processing of O.
P. Develop High-Level Designs	6. Develop Design Alternatives	Chapter 3 and the IRB proposed activities align. Label for Chapter 3 is only slightly modified for the purposes of clarity.

Table N.4: Comparison of Activities (contd.)

Chapter 3 Activities	IRB Proposal Activities	Comments
Q. Review High-Level Designs	7. Design Alternatives Review	Chapter 3 and the IRB proposed activities align. Label for Chapter 3 is only slightly modified for the purposes of clarity.
R. Analyze Design Review		This Chapter 3 activity was added to clarify the need for this type of post-processing of "Q."
S. Develop Visualization Prototype	8. Medium-fidelity Prototyping	Chapter 3 and the IRB proposed activities align. Label for Chapter 3 is modified only slightly for the purposes of clarity.
T. Review Visualization Prototype	9. Medium-fidelity Prototype Evaluation	Chapter 3 and the IRB proposed activities align. Label for Chapter 3 is modified only slightly for the purposes of clarity.
U. Adjust Prototype	10. Prototype and evaluation experience modification per feedback collected in step 9	Chapter 3 and the IRB proposed activities align. Label for Chapter 3 is only simplified.
V. Industry Public Evaluation	11. Industry Prototype Evaluation	Chapter 3 and the IRB proposed activities align.
	12. Dissertation/ Design & Evaluation Report	This IRB proposal activity is not listed in Chapter 3. This document is the execution of this activity.
	13. Final/ Presentation of Design & Evaluation results, Self-assessment and Future Work	This IRB proposal activity is not listed in Chapter 3. The final oral exam will be the execution of this activity.

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